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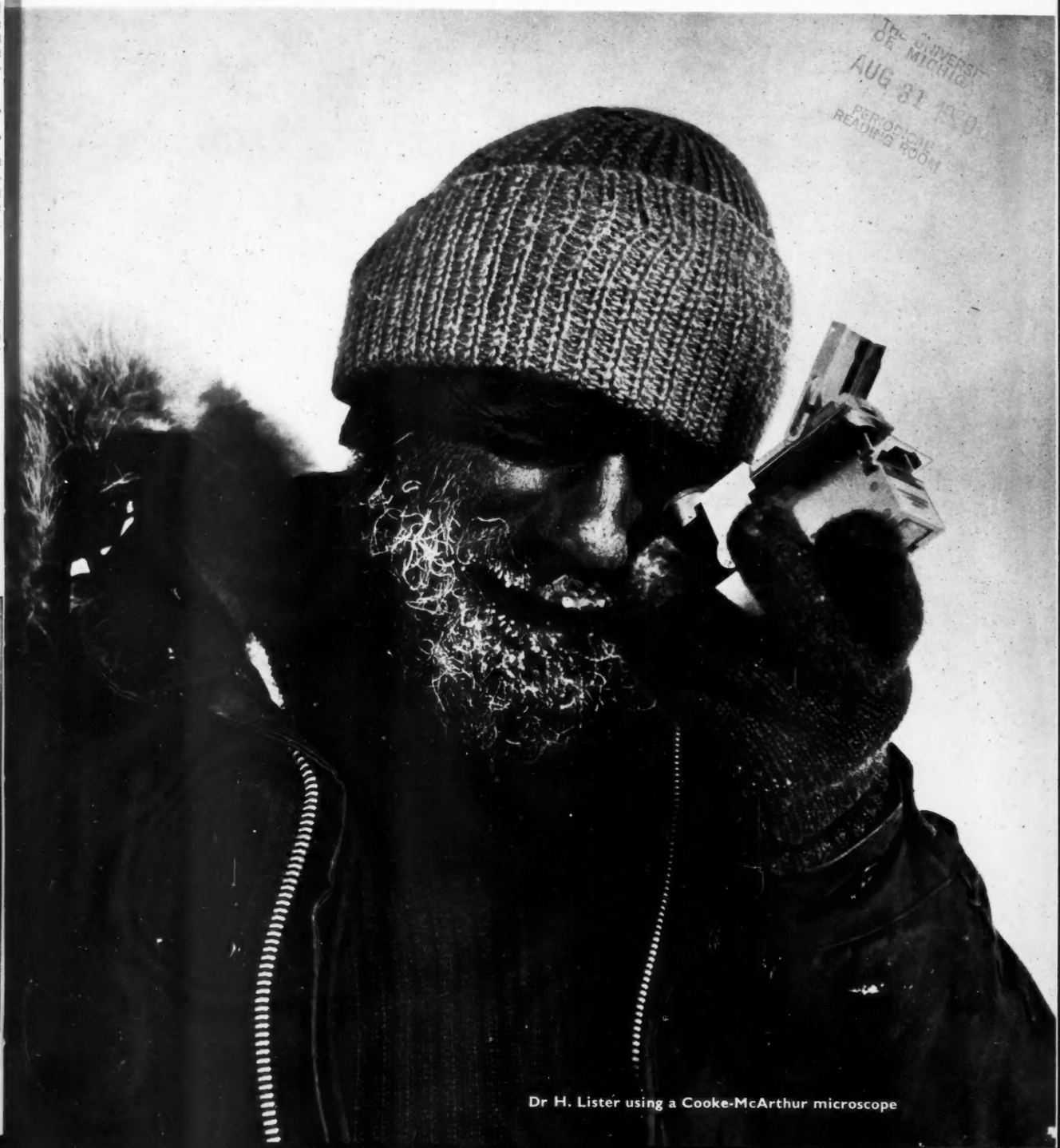

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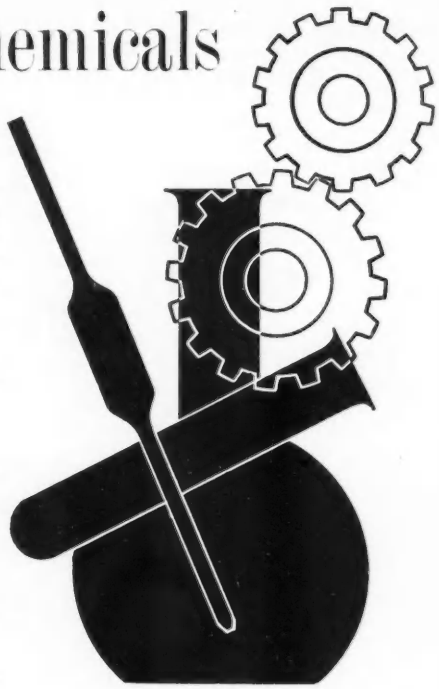

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OUR COVER PICTURE

Dr H. Lister, of the Trans-Antarctic Expedition, using a Cooke-McArthur microscope on the Ross Ice Shelf, approaching the South Pole. (See p. 356)

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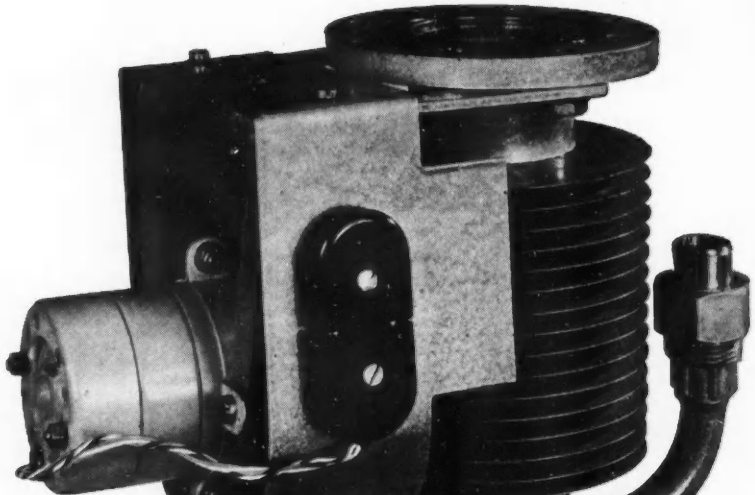

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THE PROGRESS OF SCIENCE

PROGRESS AND THE SMALL FIRM

Does Britain's industry spend enough on research, and is it sufficiently science-minded? At first sight, the signs are encouraging. The recent years have shown a steady growth in industry's science outlay. According to an authoritative estimate, "expenditure in the industrial laboratories and development departments of Britain was a thousandth of the national income in 1928, about 1/400th in 1938, and nearly 1/100th in 1958",* and the position has certainly improved again since these words were written. Nevertheless, it would be foolish to be complacent. The signposts are at best confused and some are unquestionably pointing in the wrong direction. In evidence, we refer to a recent American study of quite exceptional significance—a report on Britain's scientific and technological manpower, prepared for the U.S. President's Committee on Scientists and Engineers.† Space does not permit us to do justice to its main findings, but we would stress its submission that funds for British research would have to be increased by one-third in order to match on a population and purchasing-power basis the equivalent U.S. effort. Even more significant is the realisation that the proportion of research carried out *in* industry in Britain is lower than that in the U.S., and the proportion paid for *by* industry, and not by implication the Government, is noticeably lower. That British industry is still hampered by a tradition inimical to science is an allegation which we cannot afford to disregard.

Of course it is difficult to indicate precisely what must be done to remedy this position. It is equally difficult to establish any rigid pattern. Scientific progress frequently occurs in fits and starts: often it is a matter of unexpected "breakthroughs" in particular areas. Yet there must be an *optimum* balance in the disposition of scientific resources if technical innovation is to be most effective, and this balance must have regard not only to the overall disposition as between basic research, applied research, and development generally, but also to the intensity of effort as between different industries and sections of industry. The fact that in Britain certain science-based industries, for example, aircraft, electrical engineering, and chemicals report a high outlay on research and development, whereas certain of the more traditionally based industries, notably clothing, paper and printing, textiles, leather goods, food, drink, and tobacco, record low figures, does not *ipso facto* mean that these industries are backward in the widest sense. Nevertheless the evidence which is building up as to the impact of research on productivity, and therefore profitability, is such that one is bound to look with a more than critical eye at sectors where the scientific effort appears to be lagging.

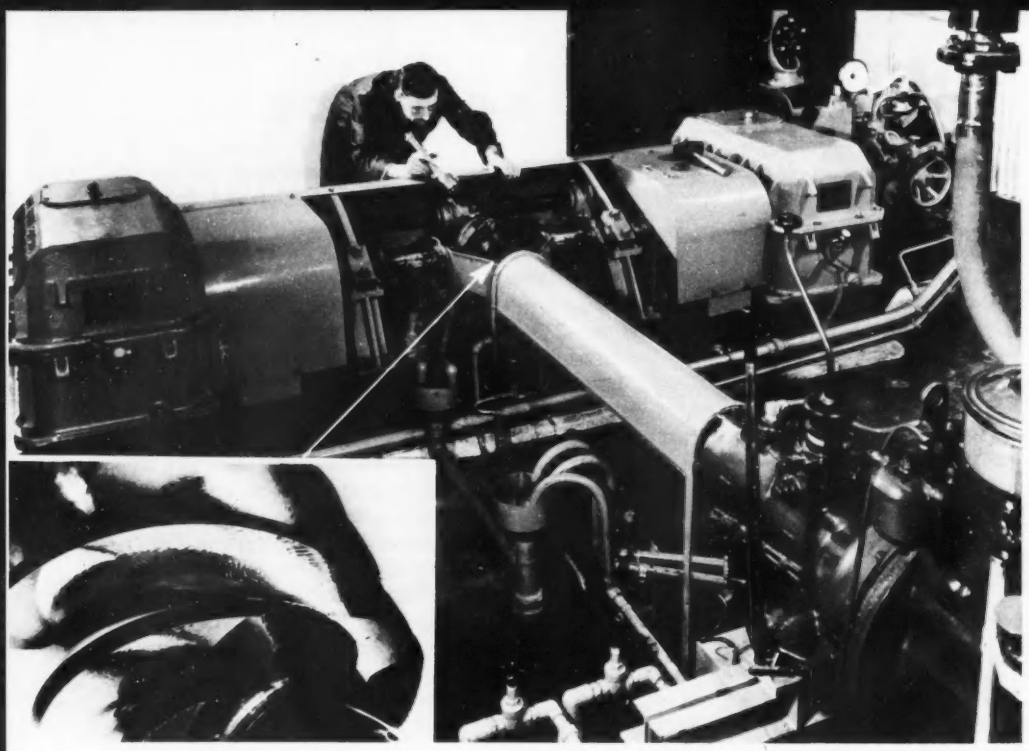
Here again generalisation is impossible but one observation, *vide* DSIR reports, is certainly valid. The research effort of industry is overwhelmingly concentrated in the "large firm", and is greater even than the concentration of production. The position *pari passu* is very much weaker in smaller firms. Bigness, of course, conveys no automatic merit: indeed, there are numerous attributes in the enlightened small firm, not least managerial and organisational, which large companies themselves will, on occasion, seek to create. But for all that, size of firm may pose a limitation to balance scientific advance. Most small firms cannot afford to employ scientists on research and development; some 250 employees are required to sustain even a minimum research unit of a single scientist. This limitation is bound to be crucial, for most research units must be larger than this. Indeed, given the unpredictability of much research, it is impossible to expect a small undertaking to run the risk of advancing research along a narrow front alone. There is, we fear, a distinct danger that such circumscriptions could paralyse the scientific up-to-dateness of British industry. Thus, a report by the European Productivity Agency, based on a sample survey of smaller firms in the U.S.A. and Western Europe, and entitled "Technical Information and the Smaller Firm" is more than disturbing from the British standpoint. It shows conclusively that so far as the totality of organisation for technical information is concerned, the proportion of firms at a low level is far greater in Britain than in the U.S. or Germany.

It is to our mind the poverty of scientific communication within the small firm area which needs the most urgent attention. Scientific research, important though it is, is not necessarily an equivalent of scientific up-to-dateness. There are many small units whose very nature precludes research activities, which can notwithstanding remain in the mainstream of technical innovation. This condition depends on two considerations: the adequacy of the scientific communications system within the industry, and the scientific calibre of staff within a firm. The latter item is crucial. We have had occasion in past issues of DISCOVERY to warn against the draining-away of our scarce and precious scientific manpower, not only overseas, but into industrial administration. However, we should recognise that business-management cannot but benefit from an admixture of scientists, and that so far as small industry is concerned, probably the only effective way of creating a scientific climate must lie in the establishment of a science-minded personnel. Our ideal must be to make "business-man" and "scientist" synonymous. Only thus can backward industries be purged of the seeds of ever-growing deterioration.

Of course this is not the full story. We recognise that in small-firm industries, technical innovation will come mainly from outside, that is, from research associations, either state or co-operatively financed, and even to some extent from competing commercial research bodies. We concede moreover that the strategy of the research associations is of exceptional significance, that their policies and the ways in which they are able to disseminate knowledge in an intelligible form could be decisive. An industrial strategy by the State, with priorities for research and development outlay is equally vital. But given all these considerations, it is only with a healthy scientific leavening in all ranks of the economy, not least the small-firm sector, that progress can be made and that we can accomplish that large leap forward in applied research which is vital for British industry.

*C. F. Carter and B. R. Williams, 1959, "Science and Industry, Policy for Progress", Oxford University Press.

†G. L. Payne, "Britain's Scientific and Technological Manpower", Stanford University Press, Oxford University Press.



Thornton's hypoid gear rig, in which a diesel engine drives a heavily loaded rear-axle assembly at low speeds. Inset is shown "rippling"—a form of pinion-tooth surface-marking often experienced under these conditions.

NEW CARS NEED NEW LUBRICANTS

In the automotive industry streamlining is the order of the day. To accomplish this effect, designers have tended to reduce the height of vehicles. Any doubts on this score can be dispelled by comparing a 1960 car or truck with a 1950 model. This trend, of course, has lowered the centre of gravity and enhanced road stability at the high speeds possible on the new motorways that are being built to accommodate today's traffic.

These styling changes, which often appear to be only concessions to popular taste, actually start a whole series of engineering modifications that require the talents of engineers, metallurgists, chemists, and physicists before they can be incorporated in the new models. Research teams, for example, have to study the behaviour of the engine components that have been re-designed and re-located in order that the bonnet may be re-styled. In fact, the adaption of fuel injection to the car engine was stimulated by the need to dispense with the carburettor on advanced models that featured a low bonnet.

An equally interesting example is apparent in the bevel gear used in the back axle of all cars and trucks. These gears transmit the power from the engine to the road wheels, and as the stylists reduced the height and hence the road clearance, these gears took on a new design, known as the hypoid gear. In this design, the teeth of the gears contact at an offset angle. As a result, the teeth are subjected to very high forces or loadings, and there is a high degree of tooth sliding which can cause excessive wear. These problems are aggravated as engine power goes up and road speeds increase.

Protection of these gears is accomplished by the gear lubricant—a special gear lubricant that prevents the gear surfaces coming together and welding under the heat developed by the combination of high sliding speed and the shocks resulting from rapid acceleration and quick stops. Thus, the lowering of the silhouette of the modern car has brought about a specially designed gear and the requirement for an extreme pressure lubricant to lubricate this gear.

Certain designs of axle are more severe in their lubrication requirements than others, particularly during the early life of the gears before they are run or broken in. At the Thornton Research Centre of Shell in Cheshire, England, as well as in many other lubrication research laboratories, continuous studies are made of the hypoid gears in automotive equipment and special tests have been developed to evaluate lubricant performance. In this way, lubricants capable of meeting the latest demands of the motor industry are developed.

For example, in shock tests a fully laden car is driven at high speed, the engine disengaged by the clutch and switched off. The clutch is then abruptly re-engaged against the static engine, imposing a heavy shock load against the gears. This procedure is repeated a number of times in each gear. To assess the performance of oils under high-load and low-speed conditions, as experienced in trucks or cars towing caravans, hypoid gear rigs are used. This simulates conditions representing a steady drive, fully laden, up a severe incline for some 300 miles non-stop.

Tests are also carried out on the test-track at the Motor Industries Research Proving Ground, Nuneaton. Here commercial-type vericles, again fully laden, tow the MIRA road dynamometer round the circuit, simulating a steady drive up severe inclines.

Fully instrumented MIRA road dynamometer drawn by hypoid-geared vehicle. This condition represents a continuous steady drive up severe inclines.
(Photographs by courtesy of Shell)

By using these and other tests, oils have been developed to satisfy the most exacting axles during the critical run-in-period. Experience gained during this work materially assists the development of gear lubricants to meet the requirements of future designs and operating conditions of hypoid geared axles.

THE INTELLIGENCE UNIT OF THE COUNCIL FOR NATURE

Early in 1959 the British Broadcasting Corporation made a grant of £5000 a year for three years to enable the Council for Nature to set up an Intelligence Unit. The Unit acts as a clearing house and information centre on natural history, serving naturalists, the Press, broadcasting and television, and the general public.

The Council itself was founded in 1958 to act as a central co-ordinating and representative body for natural history societies. It now has 210 member societies, who are its only voting members. Individual sympathisers may contribute to the Council's funds as subscribers or associates.

The Intelligence Unit started work in May 1959, with Mr R. S. R. Fitter as its Director. Later in the year Mr Stanley Jeeves joined the staff of the Unit as Films Officer and Miss Susan Kenyon as Assistant to the Director. On the intelligence side the main task so far has been to build up a body of information on sources within the natural history movement, but a steady flow of queries on a wide range of subjects is also being answered. The unit aims to put inquirers in touch with likely sources of information rather than itself answer factual queries direct; that is, it prefers to tell the inquirer the names of the leading experts or of the standard work on, say, the badger in Britain, rather than itself attempt to supply information about the diet or gestation period of the badger. An attempt is being made to trace all workers, amateur or professional, who are undertaking research on some British wild animal or plant.

Most of the energies of the Unit's first year have gone into developing the work of the Films Officer. This consists on the one hand of advice and training for amateur cinematographers interested in making films of wild life, and on the other of ascertaining what natural history films are at present available for showing in the British Isles. The latter work is undertaken in conjunction with the Botany Department of the University of Oxford. It is hoped by the end of 1960 to have a comprehensive list of films suitable for showing by local natural history societies and other interested bodies.

On the training side, the Films Officer has held three one-day courses for beginners, two in London (of which one was devoted entirely to editing) and one in Manchester. In May and September 1960 one-week residential courses are being held at Brantwood, Ruskin's old home on the shores of Lake Coniston, which now belongs to the University of Manchester.

To encourage the production of better natural history films, the Council for Nature is conducting two competitions, one in collaboration with the BBC, which is offering a first prize of £500. Particulars of both competitions and future training courses may be had from the Films Officer, Council for Nature, 41 Queen's Gate, London S.W.7. The same address also applies for natural history queries of all kinds.

MAGNETOHYDRODYNAMICS

The greatest challenge to the engineer concerned with generating electrical power is the inevitable loss which occurs when using the normal cycle of burning fuel to create steam, and using that steam to drive the turbine which in turn powers a generator of the electromagnetic type. No efficiency greater than about 41% or 42% can ever be hoped for when using this method: and no other method has, up to recent times, emerged as a possible starter, in the commercial sense, for large-scale power generation.

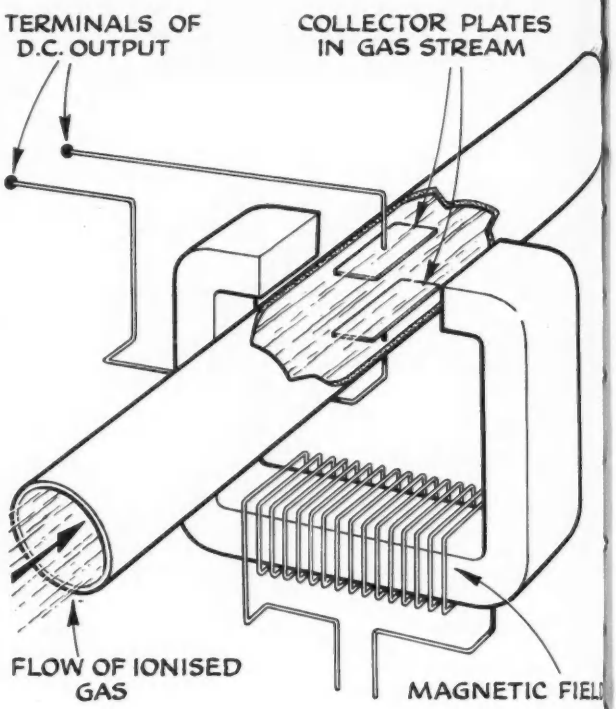
Now it appears, from research carried out by the Avco-Everett Research Laboratory in the United States, backed by ten power companies, that a new method, capable of giving about 65% efficiency, might be a challenger to the established system.

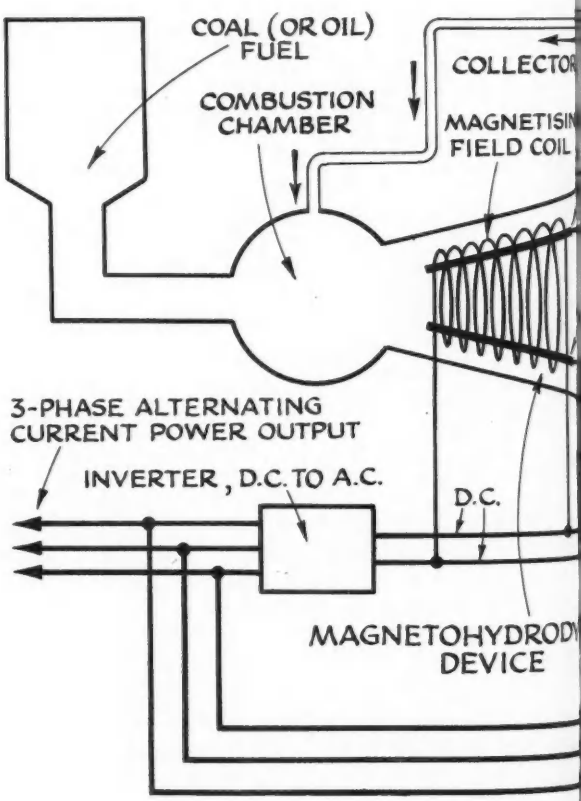
This method is known as the magnetohydrodynamic method, and depends on the obvious fact that an ionised gas is a conductor of electricity, and can be made, when under the influence of a magnetic field, to behave in much the same way as any other conductor such as the copper wire in the rotating part of a dynamo.

The magnetohydrodynamic generator causes the gas (which may be air or some other gas such as helium or argon) to become ionised by raising its temperature. It could also be ionised by forcing it through an electric discharge. However, in the proposed commercial system, a model of which with a capacity of 10 kW has already been made, air is used and is ionised by being heated by solid fuel and then forced through an electric arc. It is then driven through a powerful magnetic field in which there are collector plates. Across these plates there is set up a direct current potential which may be drawn off and inverted to produce A.C. for transmission to the normal electricity supply mains (see fig.).

Proposals for large-scale models include a coal-fired scheme where the furnace gases would be raised to 4000°F and would be seeded with very small quantities of potassium to increase their conductivity. The heat remaining after the gases had been passed through the magnetohydrodynamic generator would be then used in an ordinary steam generator. In this way it would be expected that an overall efficiency of 55% to 65% could be achieved. There seems to be no upper limit to the size of these devices, and thus there could well be a totally new conception of power-generating plant emerging from the development of magnetohydrodynamics. However, the problems of corrosion of the collector plates at these high temperatures might well give rise to severe problems: and from the cost point of view the inversion equipment for very large currents at low voltages would be very expensive. Nevertheless the American power companies who have backed this research are unanimous in thinking that it offers valuable possibilities and they are prepared to spend about $200,000 on a prototype model for 100 kW output which should yield useful experimental results.

(*For a discussion of the theoretical basis of the new subject of Magnetohydrodynamics see* DISCOVERY, 1958, vol. 19, No. 7, p. 291.)





AUSTRALIA'S NEW RESEARCH PROJECTS

The Eleventh Annual Report of the Commonwealth Scientific and Industrial Research Organisation for the year ending June 30, 1959, has now become available. The Report is a long and technical document covering the wide varieties of scientific researches being undertaken by CSIRO in such diverse fields as entomology, animal health, plant industry, forest products, industrial chemistry, and radiophysics. It outlines work on hundreds of projects of importance to Australia's primary and secondary industries.

Work on rainmaking, mineral deficiencies of soils, sheep and wool research, prevention of evaporation and many other major projects are already well known. The following paragraphs relate to a few items of special interest which have not yet received much publicity. Two new research units have been set up. Firstly, a wheat research unit has been formed. It will be financed by monies levied under the 1957 Wheat Research Act. During the year Mr M. V. Tracey was appointed Leader of the unit. Mr Tracey came to Australia from the famous Rothamsted Experimental Station in England. The new unit will investigate factors affecting the quality of Australian wheat. It will be housed in a wing of the new laboratories being built for the Bread Research Institute at North Ryde, a Sydney suburb.

Secondly, at the request of the Minister for Territories, CSIRO decided to establish a Rice Research Station on the coastal plains near Darwin. At this station studies will be made of nutrition and water requirements of rice and the possibility of developing varieties well suited to the local conditions. The results of these investigations will be applicable to areas around Humpty Doo, where attempts have been made to grow rice for some years. Scientific research should reduce the uncertainty and hazards of rice-growing in these areas.

Another new project deals with survival of new-born lambs. Scientists at the Sheep Biology Laboratory at Prospect, New South Wales, have been trying to find out why new-born lambs die in bad weather conditions. The laboratory is equipped with special rooms in which cold and wet weather can be artificially produced. A striking difference in resistance to exposure was found between lambs from well-fed ewes and lambs from poorly fed ewes. Even if the ewes have been well fed, it is imperative that lambs receive nourishment very soon after birth.

In one very interesting experiment maiden ewes (ewes which had not yet produced a lamb) and mature ewes were closely watched through pregnancy and lambing. It was discovered that over 20% of the maiden ewes abandoned their lambs, compared with only 1% of the mature ewes. Apparently the pain and shock associated with giving birth for the first time represses the normal maternal instincts of ewes.

An Australian oil company, H. C. Sleigh Ltd, has made a grant to enable CSIRO to undertake a research programme on solid lubricants. Several new substances derived from Australian minerals might be used. Typical examples are chemicals called zirconium sulphide and titanium sulphide.

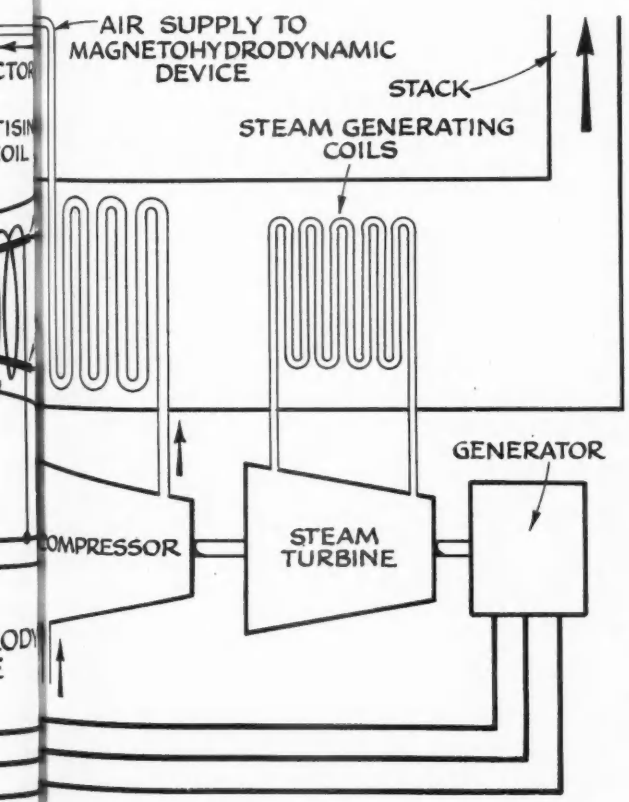
The new materials show promise for application in the same way as graphite. The research will be carried out in the laboratories of the Division of Tribophysics (tribophysics means the study of friction). Scientists in the division started working on the lubrication of bearings during the last war.

For some years the CSIRO Division of Building Research has been interested in the use of lightweight concrete in buildings. Scientists in the division have developed methods for making lightweight aggregate from Australian clays. This aggregate replaces stone screenings in concrete-making.

This year's annual report notes the acceptance of the new material. Three plants for the production of aggregate have been built—two in Sydney and one in Melbourne. A demonstration house, built of the new lightweight concrete, has been constructed by the Victorian Housing Commission.

(*Left*) Diagram of the magnetohydrodynamic device proposed.

(*Below*) Diagram of the electrical lay-out of the proposed commercial generator.



A PRE-COLUMBIAN ISLAND

In a wind-blown, white sand desert of northern South America a nomadic, polygamous, matrilineal race of Indians has maintained its independence and ways of life for nearly five hundred years. The people of this cultural island, the Guajiros, are described by Dr Raymond E. Crist of the University of Florida in a report recently published by the Smithsonian Institution.

In spite of their proximity to the western cultural influences of Venezuela and Columbia these nomads only now are beginning to succumb to the influences of the outside world. In about as inhospitable an environment as could be imagined, they represent an almost unique phenomenon in this part of the world. In ways they resemble the nomad Arabs of the Sahara.

The great waste of sand and bare rock, the Guajira Peninsula, never was actually subdued by the Spanish Conquistadores, the report points out, although all neighbouring tribes were easy victims. Although the white men made many half-hearted attempts to conquer the desolate peninsula by force, says Dr Crist, the land was not rich enough in gold or precious stones to justify an all-out effort and the natives waged an incessant, bitter war against all outsiders.

Notable is the survival of the matrilineal, polygamous family. According to Guajiro law, a man acquires a wife by purchase from her family, paying in cattle, horses, goats, sheep, and perhaps in some costly jewellery. Consequently, a girl child represents a certain amount of wealth that will come to her family with the bride price, whereas a boy child represents an economic drain, since the family must get together the bride price. Thus, Dr Crist points out, much better care is taken of female children, which is reflected in the infant death rate.

Blood relationship was traced almost entirely through the mother. Children "belong" to mothers, not fathers.

The people, it is related by Dr Crist who has spent some time among them, are divided into various clans or blood groups, each with its distinguishing totem representing the animal with whose traits, according to legend, the clan was originally imbued. For centuries each clan was theoretically on a war footing with all other clans. Blood feuds were common and marriage was only inside the clan. Formerly each member of a clan was considered a relative of every other member, but in the course of time, Dr Crist reports, the close relationship of any member came to be restricted to his mother and her ancestors, her brothers and sisters, and their descendants. Thus the father dropped out of the picture and the head of a group became the maternal uncle.

But within the past few years, Dr Crist found, Guajiro culture has loosened its grip as some former nomads settle in villages at strategic points of contact between Indian and Latin-American culture, while others seek employment in nearby cities. Especially where there is marriage according to the rites of the Roman Catholic Church, does the Christian pattern of paternal status for the breadwinner make its appearance.

The Guajiros remain, however, the last large group of Indians of northern South America to retain intact many aspects of their pre-Columbian cultural heritage.

COMMUNICATIONS: CONTACT AND CONCERT

Within this past year, the twenty-fifth anniversary of the Daniel Sieff Research Institute was commemorated. Its history of growth and metamorphosis into what is now known as the Weizmann Institute makes an excellent case history of the development and maturation of a type of a modern research institute.

The story reads as follows: An initial interest in one particular field—in the case of the Sieff Institute it was Weizmann's own organic chemistry. It could have been medicine, physics, any area of science or technology. The usual beginnings were housed in simple laboratories, but they expanded and extended into many avenues. Chemists, joined by microbiologists, physicists, mathematicians, and biologists start exploring areas of mutual interest. These areas, not yet sharply defined either by a heritage of tradition or by a great body of cohesive substance, are thus extended and expanded; and so, too, the whole realm of scientific inquiry. Where once a simple set of equipment and elementary instruments sufficed, now fantastically intricate and complicated instrumentation become basic requirements. Where once each could enjoy the essential luxury of individuality, now collaborative effort becomes the order of the day. The independent spirit remains, for without it there is no true scientific achievement, but meshed with individuality is the integrated effort.

Even to the untrained eye, the massive physical growth and expansion of the modern research institution bespeaks an infinitely increased complexity. The Weizmann Institute in Rehovoth, the Pasteur in Paris, the Rockefeller in New York, the Karolinska in Stockholm, the Carlsberg, in Copenhagen, or the Chester Beatty in London, are examples to give evidence to this growth. This complexity, the very essence of the 20th century, has presented science of today with a quandary. The possibilities become less and less for scientists who are trained in one or two disciplines, to attack areas of ignorance single-handed. Scientists from many disciplines must fuse their talents and techniques. Biologists are involved in physics and chemistry; chemists enlist the co-operation of physicists and mathematicians, and delve into fields of biology. Medical investigators require the knowledge and technical assistance of all basic sciences, and lean upon aid from electronic and mechanical engineers.

With this complexity of current scientific research comes a direct by-product: the fantastic increase in costs. Costs of instrumentation, of services, of staff, even of means of communication, publication of journals, scientific conferences. And as more special fields are incorporated in the attack on a research problem, the costs multiply.

One way to the partial solution of this problem, is the team approach in which a physicist, a chemist, a biologist, and an engineer, are directed by a group leader. Of course, the basic requirement for successful operation is the existence of an effective system of communication.

Although communication between these members—all scientists—may make demands for new publications and even new symbolic language, it is essentially fluid and

effective. On the whole they manage to understand each other. In fact they must.

Quite different, yet critically pertinent, is the role of another "member" of the team who works neither in the laboratory nor in the field, but plays his part in helping to give financial support. He may be the citizen tax-payer, the stockholder, friend, or donor, but he is a newcomer and usually has a different background. His participation is not comparable to that of a charity donor; it is essential to the vitality and viability of his modern civilisation. Technology, the base of modern civilisation, is his making, not the scientist's or the engineer's. The scientist may gather the information; the engineer may transform it; but it is only the society which promotes, rather, permits the development of technology by demanding and *utilising* technology. Here then we have today a new member of the team—working not to do the research, but to help support it, and to nurture and accept its realisation.

From the two points of view, of nurturing research and creating technology, this communication between the scientist and layman is as a thread of life for both, and a bridge not only for a way of living, but for a way of life. Yet this diversity of the membership of scientists and, shall we say, humanists, makes need for caution. For it was the late George Sarton,* greatest of all historians of science, who rightly pointed out that the ominous conflict of our time is the difference of opinion, or of outlook, between humanists (he said "so-called humanists") on one side and scientists on the other. Why is this?

The rate of scientific discovery and the dynamic structure of society have a critical relationship which is of utmost importance to those who wish to understand society, and even more so, to those who wish to modulate or control the changes which are occurring. Here, unfortunately, the dichotomy appears to us with foreboding: the cleavage between scientific knowledge developed from observation of facts and their classification into pattern, and history or humanistic learning (or the study of accumulated thought of mankind as it is transmitted to us). Mees† says, "The separation of these two types of learning has always been unfortunate; at present it is serious, and it may, indeed, be disastrous."

The disastrous can come from inability to establish proper communications between these two partners; for whether diversity or dichotomy exist, the fact remains that partnership cannot be denied and co-operation must be achieved.

Hafstad‡ invites attention to the principle in physics which states that in order for energy to be transmitted efficiently from one electrical network to another it is necessary that there be an impedance match between the two circuits. Similarly, for transmission of information, more accurately human understanding, between two individuals there must be matching of backgrounds. Although matching between scientists exists, and matching between humanities is sufficient, there is an historical lack of impedance matching between devotees of sciences and the humanities.

Since our team consists of scientist and the humanist, and since our civilisation is overwhelmingly dependent on advances in science and technology, every effort must be made to decrease the impedance mis-matching in communications.

Regrettably, scientists (and engineers) are notoriously inarticulate in communicating to the layman. No less regrettable, our educational systems have failed in enabling free communication between the generally educated and the specifically scientifically oriented. Impedance matching is poor.

And yet, as Glenn Frank, late president of the University of Wisconsin, said: "The practical value of every social invention or material discovery depends upon its being adequately interpreted to the masses. The future of scientific progress depends as much on the interpretive mind as the creative mind. . . ."

Here, then, the scientist, if he holds a true allegiance to science must, in spite of inherent inarticulateness, or modest reluctance, or pressure of more fascinating tasks, make every effort to communicate his ideas of purpose and his philosophy of performance to the non-scientist member of the team. Failing to do so, he will be charged with doing himself and his endeavour in achieving scientific progress a grave, perhaps even fatal, injury. *And yet he is not alone in this.* The non-scientist, as a member of a technologically oriented society, no less than the other members of the team, must also make serious and, if need be, strenuous, efforts at matching impedance of communications. It is beholden upon him to participate in the process of mutual understanding. He must learn his part for receiving the messages of the scientist.

If within the small area of a single institute, this process of enhancement of mutual understanding can be developed, and if the communication between scientist, administrator, and public supporter can achieve a matched impedance, a community with inherent potential for expanding will result. From well-matched impedance in the tight circle of the institute, we may hope to advance well-matched impedance with society, and eventually with the State and across national frontiers.

But it is the internal process, the improvement of communication within the institute (or university) that is the essential requirement, basic and vital to the realisation of the greater relevance of science in the service of society, and it is here we must begin.

Lest this be misconstrued as a call for intense participation of the scientist in the role of propagandist, two points should be stressed. First, that feedback is essential to the success of this achievement of proper understanding; and second, that communication involves integrated systems of immense complexity which should be utilised and improved at as many links, cross-links and feedbacks as possible. In fact, it requires not that scientist become propagandist, but that the methods of science should be employed in understanding and improving our communications in order to make contact and attain concert.

* Sarton, G., 1937, "History of Science and the New Humanism".
† Mees, C. E. K., "The Path of Science".
‡ Hafstad, L. R. 1947, *American Scientist*, vol. 45.

FARMING THE SEA

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The full exploitation of the vast resources of the sea requires the control of all nutrients and of the feeding, breeding, and migration of all marine creatures. This, however, is a very long-term plan; the development of the fisheries for plankton-feeding animals offers a short-term gain.

If we mark out an area on the surface of the sea, the volume of water beneath that area can theoretically produce at least as much organic matter as the same area of the best agricultural land; and it has often been said that since four-fifths of the earth's surface is sea, the potential yield of food is very much greater than that from the relatively small amount of cultivable land. Comparisons of this sort must be viewed with caution. The nature of production in the sea is very different from that on farmland, for there is no simple transformation such as that from grass or corn to domestic animals and man.

The grass of the open sea, the plant life which uses the energy of sunlight to manufacture sugars, fats, and proteins from inorganic salts and from carbon dioxide in solution is not fixed but is part of the community of small floating creatures called plankton (Fig. 1). Sunlight does not penetrate very far below the surface of the sea, and these plants are found only in the upper layers, from a few metres to a hundred metres deep, according to the clarity of the water. They are mostly very small, and range in size from the better-known diatoms, which have shells or cases made of silica (Fig. 2), to the tiny flagellates, mere specks of green matter 1/100th to 1/1000th of a millimetre across (Fig. 3). Such plants may be present in great numbers at times, sufficient to colour the water green or brown. Some rarer forms which may colour the water red (the "red tide") may be poisonous to animal life, but the rest are the food of the microscopic animals of the plankton, which measure from a few hundredths of a millimetre to several millimetres long. These grazers, or herbivores as they are called, belong chiefly to the group of animals called crustacea, most of them being copepods (Figs. 4 and 5). The herbivores are in their turn eaten by larger crustacea and small fish, which form the prey of large fish, themselves eaten by birds and man. The complex food-chain in the sea is compared with the food-chain on land below.

Obviously, the more steps there are in a food-chain the more "wasteful" it is, and the smaller the number of animals at the end of the chain. It has been calculated that, at the average temperature of North European waters (10–12°C), 100 gm. (dry) of plant plankton is eventually transformed into no more than 0·3 to 0·03 gm. of large animals.

THE PRODUCTION CYCLE

Theoretically, the living organisms in the chain should control one another, so that at any one time or place the crop of plants would be small but enough to support the herbivores which would be present in the right quantity to nourish the larger animals, and all the time sufficient nutrients for the plants would be returned by excretion and the decay of dead organisms at all stages in the chain. In practice, an equilibrium is rarely found, and most often there are alternating cycles of abundance and scarcity of nutrients, plants, and herbivores, with the larger animals suffering periods of repletion and starvation (Fig. 6).

The plants of the plankton grow very quickly, and increase in number by division of their single cells (which sometimes remain joined together in chains). Culture experiments in artificial or enriched sea-water show that they need most of the elements also required by land plants for growth, but that in the sea, growth must be controlled principally by four factors: light, phosphorus (as phosphate), nitrogen in various forms, and temperature. For diatoms, we must add to this list silicon (as silicates). Of these principal factors, light and phosphate are believed to exercise strictest control. In the winter, at high latitudes, insufficient light penetrates the surface of the sea and the growth of plants practically ceases. During this season most of the small herbivores die (some survive by migrating to deep water of low temperature), and stocks of nutrient salts increase. In the spring, when light and warmth return to the surface layers, there is a sudden increase in the numbers of plants; this outburst of phytoplankton, as it is termed, is followed by an increase in the herbivores, and then the numbers of both decline. In arctic regions production then ceases, but in more temperate latitudes there is usually a further, less marked, outburst in the autumn before the light fails once more. Towards the tropics, these cyclical fluctuations become less extreme, and the spring outburst begins earlier. Within the tropics, light is no longer a controlling factor. Both phytoplankton and herbivores are present all year round, but some fluctuation occurs, often with a maximum in the winter months (Fig. 7).

These differences in the production cycle in different climates can be regarded in two ways. According to some theories the extent of the plankton crop is directly related to the nutrient content of the water, which (especially phosphate) is much greater in winter in high latitudes. The absence of marked outbursts in the tropical oceans is regarded as due entirely to an inherently low nutrient content of the water in those areas. From physical observation, it is known that there is little or no mixing between the surface layers and deeper water. Nutrients are alleged to be continually lost from the upper layers of the ocean

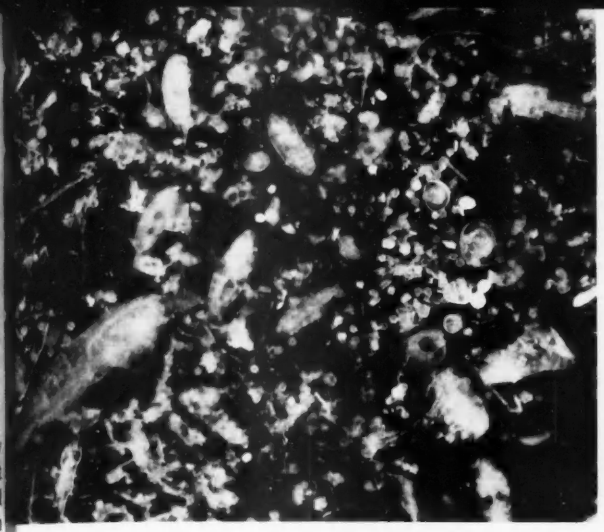


FIG. 1. Mixed plant and animal plankton (mainly copepods, larvae, and diatoms). Preserved.

FIG. 2. Diatoms found in coastal waters in the autumn.

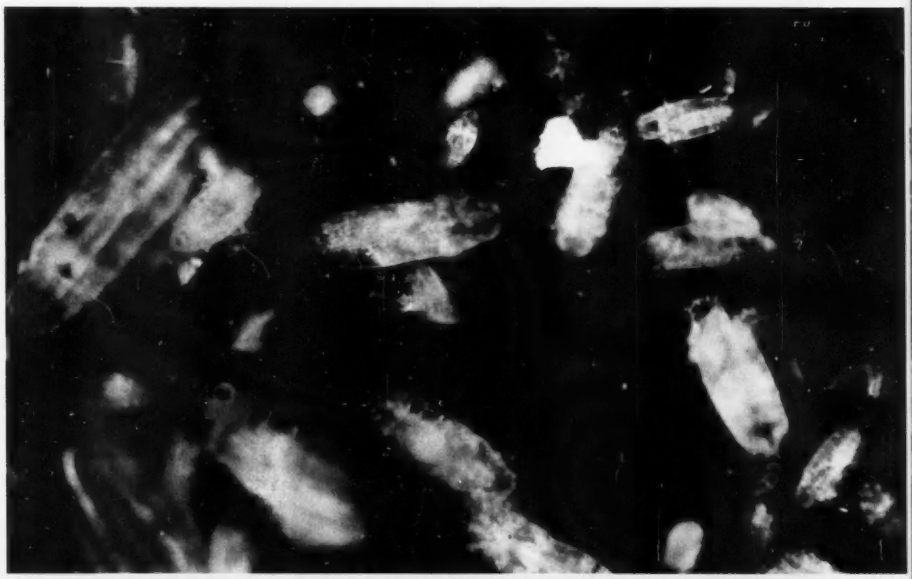


FIG. 3 (*above*). A smaller plant of the plankton, showing the flagella with which it swims.
(*Photo: Dr Mary Parke*)

FIG. 4 (*middle right*). Living plankton, mainly copepods.

FIG. 5 (*right*). A living copepod feeding on an artificial culture of plants; right, the same plants further enlarged, showing also faecal pellets from the copepod containing practically undigested plants. This illustrates the "over-grazing" which occurs in rich plant plankton.

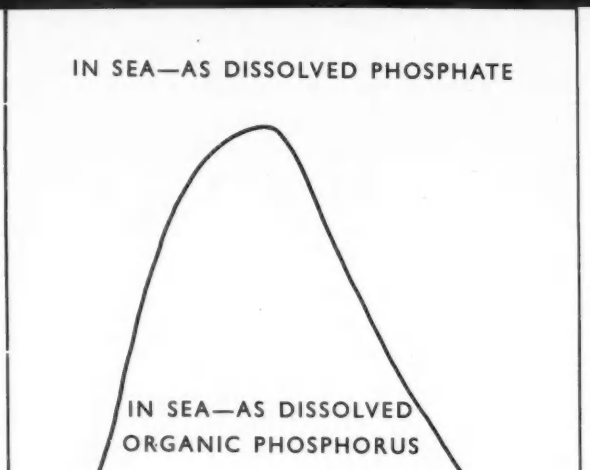


FIG. 6 (*above*). The seasonal cycle of phosphorus in shallow temperate waters.

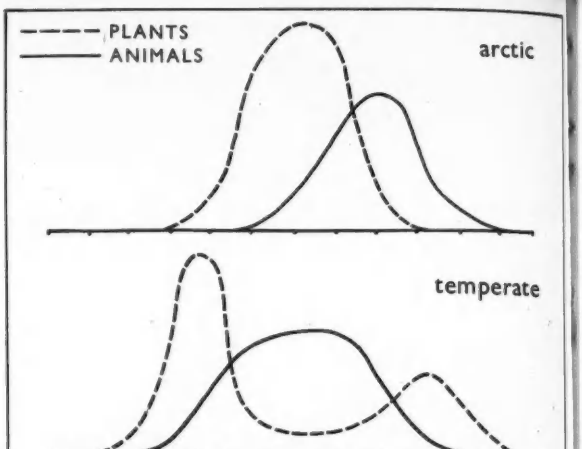


FIG. 7 (*above*). The quantities of phytoplankton and herbivorous animals present throughout the year in different latitudes, showing the smallness of the seasonal variation in the tropics.

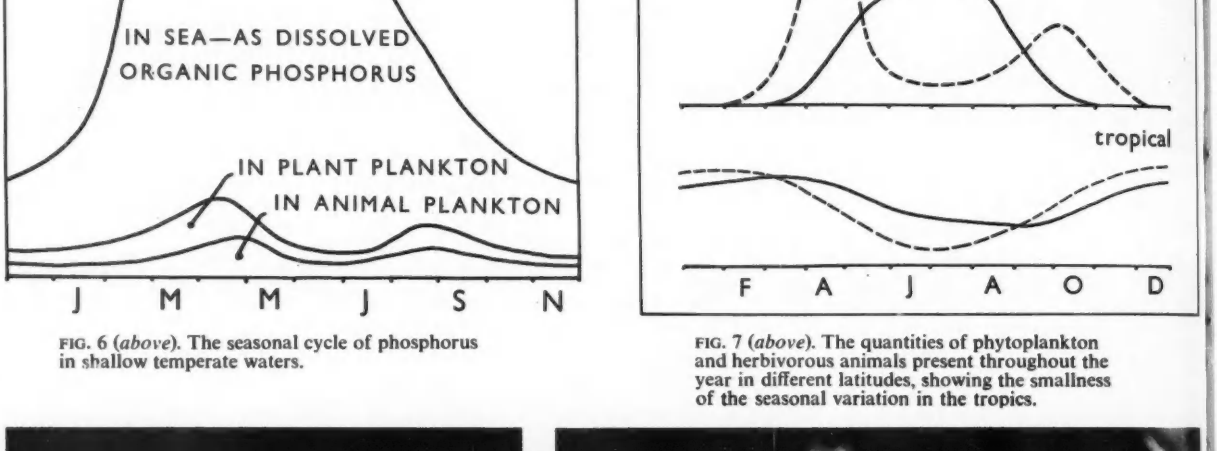
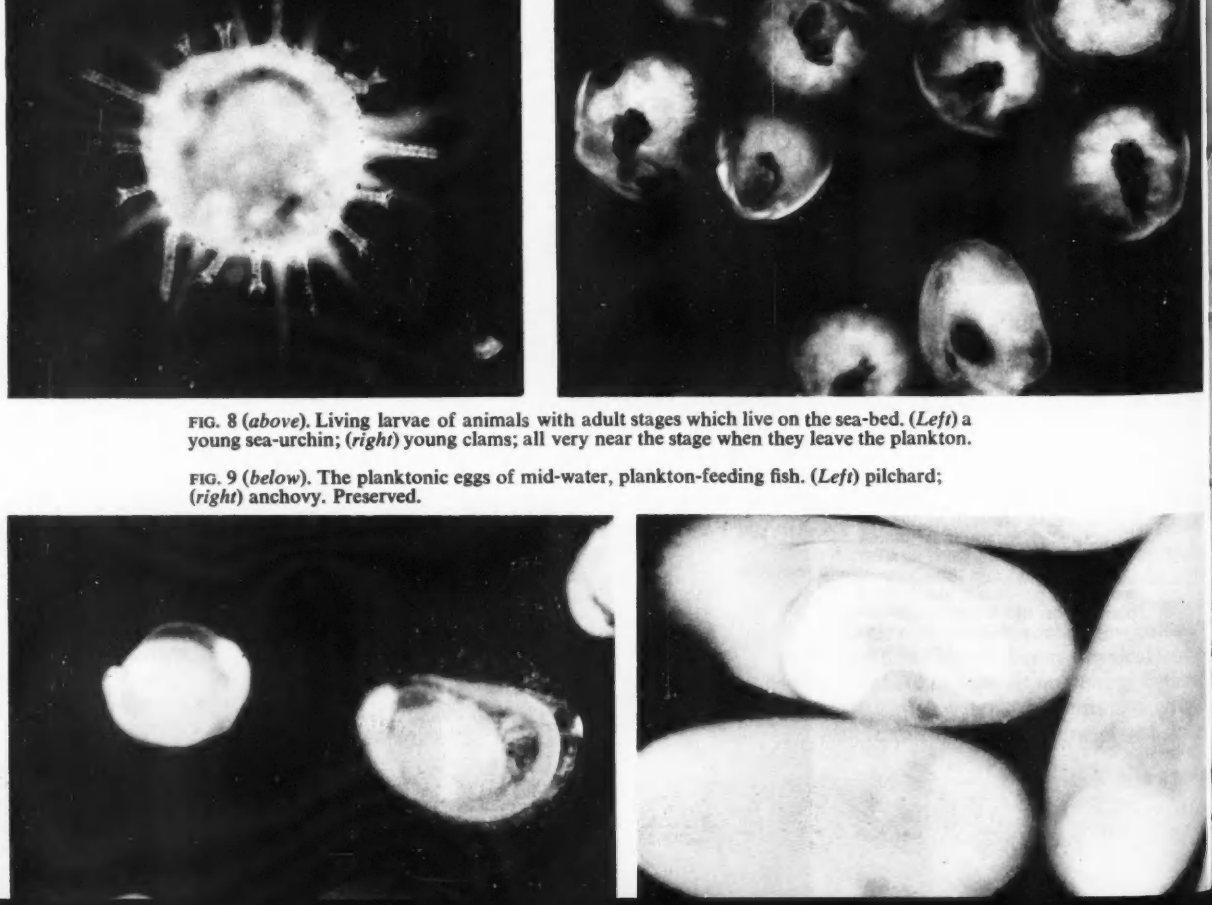


FIG. 8 (*above*). Living larvae of animals with adult stages which live on the sea-bed. (*Left*) a young sea-urchin; (*right*) young clams; all very near the stage when they leave the plankton.

FIG. 9 (*below*). The planktonic eggs of mid-water, plankton-feeding fish. (*Left*) pilchard; (*right*) anchovy. Preserved.



by gradual sinking of dead and decaying matter, and are only returned to the surface in exceptional circumstances, such as "upwelling", where the lie of the coast, and the direction of winds, result in some of the deeper layers being brought to the surface.

This view of the tropical oceans as biological deserts is losing support. If such areas are considered as showing a near or partial equilibrium between nutrients, phytoplankton, herbivores, and larger animals, as in the theoretical case already mentioned, the amount of free nutrients at any time has no relation to potential productivity, for most of the nutrients will be in circulation in the chain, and will be immediately used again if liberated into the water. Accordingly, the cooler regions of the oceans are regarded as out of equilibrium: the winter accumulation of nutrients and the summer outburst of plankton merely indicate the extent of the imbalance, and may have no relation to potential production either.

On this basis, then, temperate and arctic seas are not necessarily more productive than the tropical oceans because they show a heavy crop of plankton at one season in the year. Nevertheless, the differences in the plankton cycle in different latitudes have produced marked differences in the biology of plankton-feeding fish and other animals present. For example, among plankton-feeding fish, the species of herring are found mainly in the colder regions. Their life-cycle is geared to the seasonal fluctuations in those seas. Stores of food reserves are built up during the brief summer season of rich feeding, and breeding takes place only once a year after the total plankton crop has reached its peak (or, in a few cases, just before the next outburst). Pilchard, on the other hand, are fish of warmer seas where there is less annual fluctuation in plankton production. Their food reserves are built up over a long period, and breeding takes place several times in the year.

Similar relations to the plankton cycle are shown by animals which live on the shore or on the sea-bed when adult. Most of them produce larvae which live freely in, and feed on, the plankton for a few days or weeks before settling down to the sedentary adult existence (Fig. 8). In higher latitudes most of the larvae are produced at the time of the spring outburst of plankton: the animals which live in more tropical areas produce their larvae over a long period and show little or no synchronisation with the seasonal changes which do occur.

MEASURING NATURAL RESOURCES

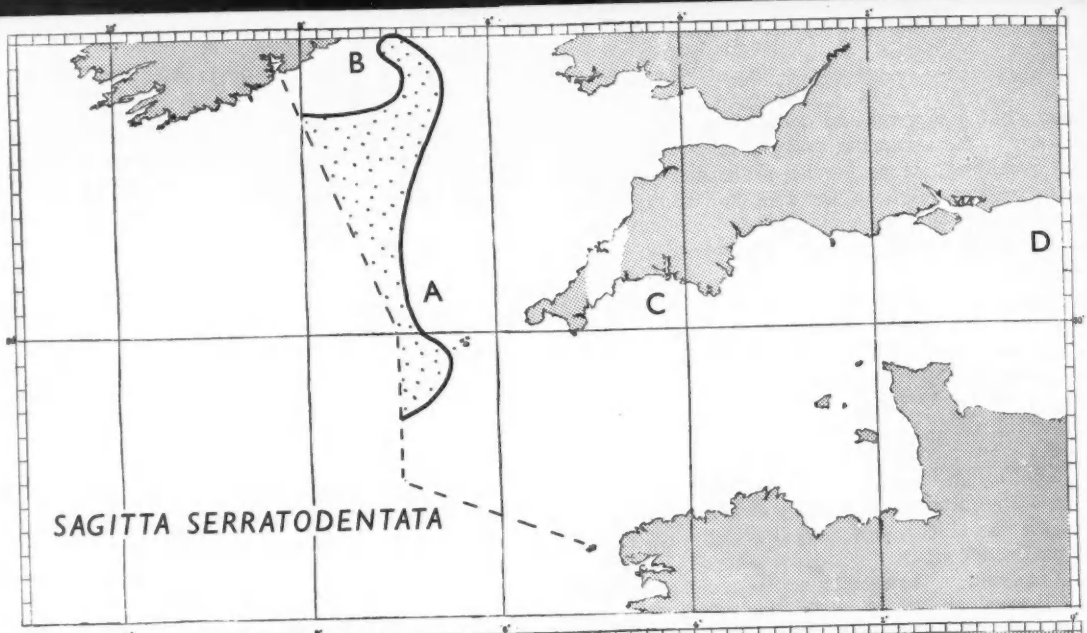
If the productivity of a given area of sea cannot be estimated from the nutrient content, how then can it be measured? Only by assessing the contribution made by all stages in the food-chain: there is no short cut at present.

The end products or near-end products of the chain, the fish, are the most difficult to estimate. For fish which are caught commercially, it is usual to estimate their abundance by marking experiments. A number of fish are caught, marked with tags, and put back in the sea. By a statistical manipulation one can estimate, from the proportion recaptured, the total number present in that area of sea and the intensity of the fishing effort. For many species, especially the pelagic (mid-water) plankton-feeding fish, it is easier to estimate the population from the numbers of eggs produced during the breeding season. Fortunately, the eggs of most species of fish are shed into the sea, where they float freely in the plankton while undergoing embryonic development (Fig. 9). Special nets of silk or nylon mesh are used to catch them, the amount of water filtered being measured by a meter at the entrance to the net, and the resulting egg counts can be converted to numbers per surface area of sea. Mature female fish are caught, and their eggs counted, and observations made on the proportions of males and females in the sea. From all these estimates the total numbers of mature fish can be calculated.

Such calculations have been made in several areas—for example, in the North Sea for plaice, and in the English Channel for pilchard. Unfortunately, herring are among the few fish which lay their eggs on the sea-bed, where they remain until they hatch. So far it has only been possible to find, and estimate the egg content of, a herring spawning-bed of a small local race in the Clyde Estuary. This work, significant though it is as an application of underwater photography and grab sampling, cannot yet be applied on a large scale in the open sea.

There remains another method of estimating the numbers of fish. The young are present in the plankton for several months after hatching, and feed on the smaller animals and plants. At this stage in their life they are fairly easy to capture. By assuming they are evenly dispersed over an area, we can gain an idea of the total population of young fish. If the estimated numbers likely to survive to the adult age are applied to this figure, a rough idea of the adult population can be obtained. Such calculations depend on the accuracy of the estimated mortality, a value which can only be approximate since it has to be derived from fuller studies made on other fish, and may vary greatly from species to species. Nevertheless, the abundance and distribution of young fish have been studied intensively, and there are many instruments specially designed to catch them. The simplest is a long conical net of sacking material, about 2 m. in diameter and 6 m. long; this is towed at slow speed while being hauled up gradually from the sea-bottom. A similar but somewhat smaller net of silk is usually hauled up vertically from the sea-bottom while the ship is at rest. Researchers in this type of work are gradually adopting what is called the high-speed tow-net, since they have found that some young fish can avoid or escape from nets towed at less than 6 knots. The high-speed net works on a simple principle: the net, usually of metal gauze, is placed inside a metal or plastic tube, to which the water is admitted, while towing, by an aperture smaller than the diameter of the net, and the actual flow of water inside the tube is reduced to a speed which does not squash the young fish against the gauze.

Estimates of the contribution to total production made by the smaller animals and plant plankton are easier. A fine-meshed silk net is towed through a measured column of water. Later, the total catch is dried and weighed, then re-weighed after burning, to give total organic and inorganic weight. The plant plankton alone can be estimated roughly by extracting the green pigments such as chlorophyll with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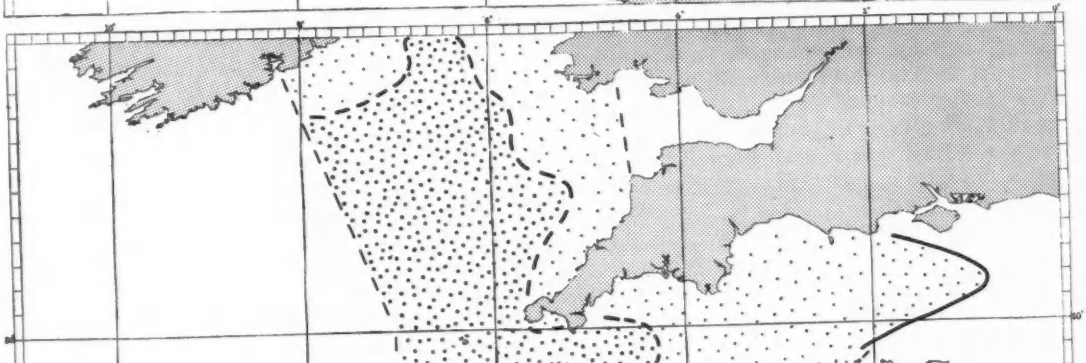
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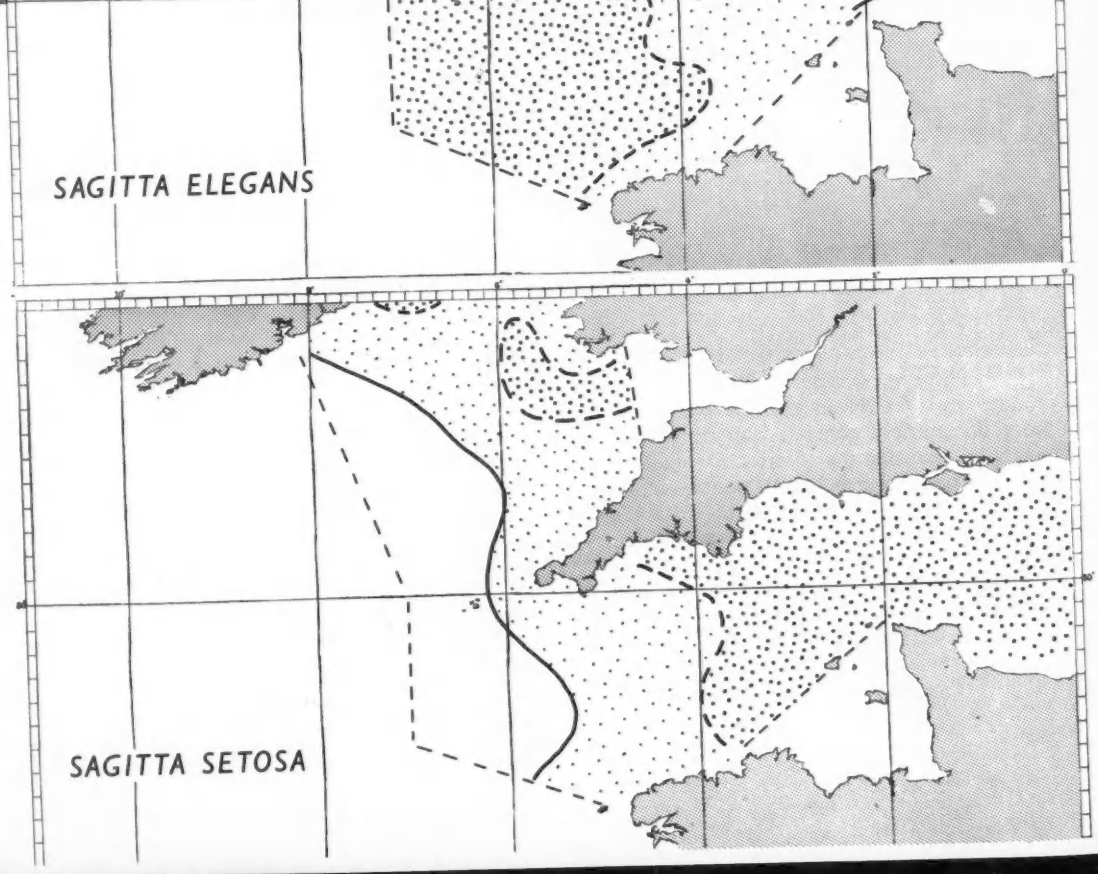
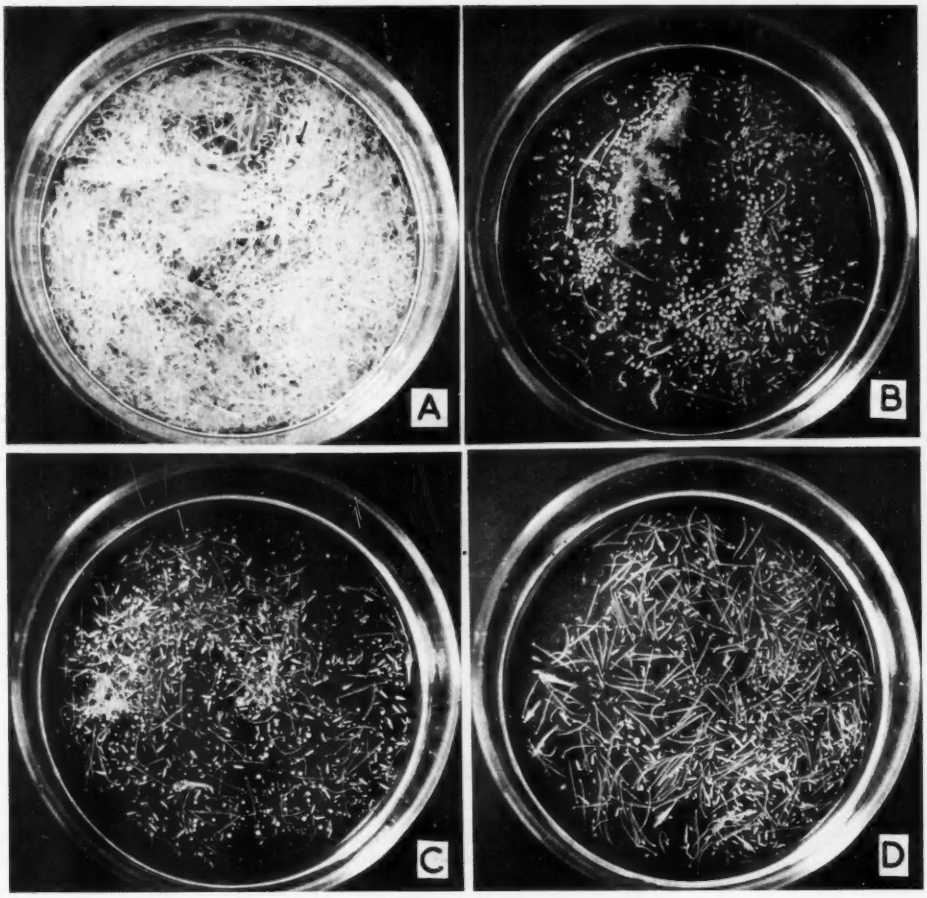

SAGITTA SETOSA

FIG. 10 (*page opposite*). Three different bodies of water in the English Channel and South-western approaches, distinguished by their plankton content, in this example by three different species of arrow-worm. Above, nearly pure oceanic water; middle, mixed oceanic and coastal water; below, coastal water. These maps are based on plankton samples taken in January and February 1959, some of which are shown in Fig. 11. The thin pecked lines enclose the area sampled. Heavy stippling indicates the region of greatest numbers of the arrow-worms (more than one to each cubic metre of water), but there is naturally some overlapping between species.

FIG. 11. (*right*). Some of the plankton samples used to draw Fig. 10, showing how the different bodies of water can be distinguished. The positions of samples are given on the upper map in Fig. 10. (*a*) mixed oceanic and coastal water, with abundant arrow-worms and oceanic jellyfish; (*b*) mixed oceanic and coastal water from a herring spawning-ground; arrow-worms less abundant, some swimming snails and phytoplankton present as well as fish larvae; (*c*) mixed oceanic and coastal water, with coastal forms (including the arrow-worm) dominant, from a region of a pilchard fishery; (*d*) coastal water only, with arrow-worms and some shrimp-like crustaceans. All samples taken with similar instruments (high-speed sampler) and similar volumes of water filtered. About seven-eighths natural size.



solvents (acetone or alcohols), and measuring the intensity of the colour. This method is more rapid but less accurate than making a direct count of the plant cells present in a volume of water after settlement or centrifuging. For scarcer forms, it is possible to make a culture of the water sample, after enriching it with nutrients, until enough cells are available for the above methods to be used.

In full-scale plankton researches, whether studied as a pure science or as part of a particular fishery problem, samples of the plankton are taken throughout the year and the variations in the component species of animals or plants assessed. Such observations can provide basic data for many calculations of production. Large-scale surveys are carried out continuously over many North European seas by a special plankton laboratory at Edinburgh. Ingenious automatic samplers are used, and are towed behind passenger and cargo ships on regular commercial lines. Other laboratories have surveyed smaller areas for many years, and as a result of all such work it has been found that the species of animals and plants in the crop of plankton change greatly from place to place, even in the narrow coastal seas. It is now possible to distinguish particular areas of sea by their plankton content, and deduce the amount of mixing that goes on between them (Figs. 10 and 11). Many of the animal predators of the plankton, the larger crustacea, arrow-worms, and small jellyfish, to name but a few, may show clear-cut associations with certain areas of water. These macroplankton forms, as they are termed, may also be associated with the type of plankton-feeding fishes present. For example, herring are often found in regions where there is much macroplankton. Pilchard, on the other hand, are rarely found together with an abundance of macroplankton; in fact, in the English Channel, the presence of shoals of pilchard, as determined by echo-sounding (Fig. 12, *a* and *c*) often means that most animal plankton will be scarce. Although pilchard must be voracious feeders, we cannot be sure if the correlation is direct.

THE SCATTERING LAYER

Echo-sounders are now used in many ways in plankton researches, as they can provide records of some of the plankton organisms as well as of large fish. The well-discussed scattering layer is believed to be due as much to heavy concentrations of macroplankton as to small fish. It takes the form of a continuous but often diffuse echo-layer, differing greatly from typical echoes produced by shoals of fish, and found at depths varying from only a few fathoms in coastal waters to several hundred fathoms in the open ocean (Fig. 12, *b* and *d*).

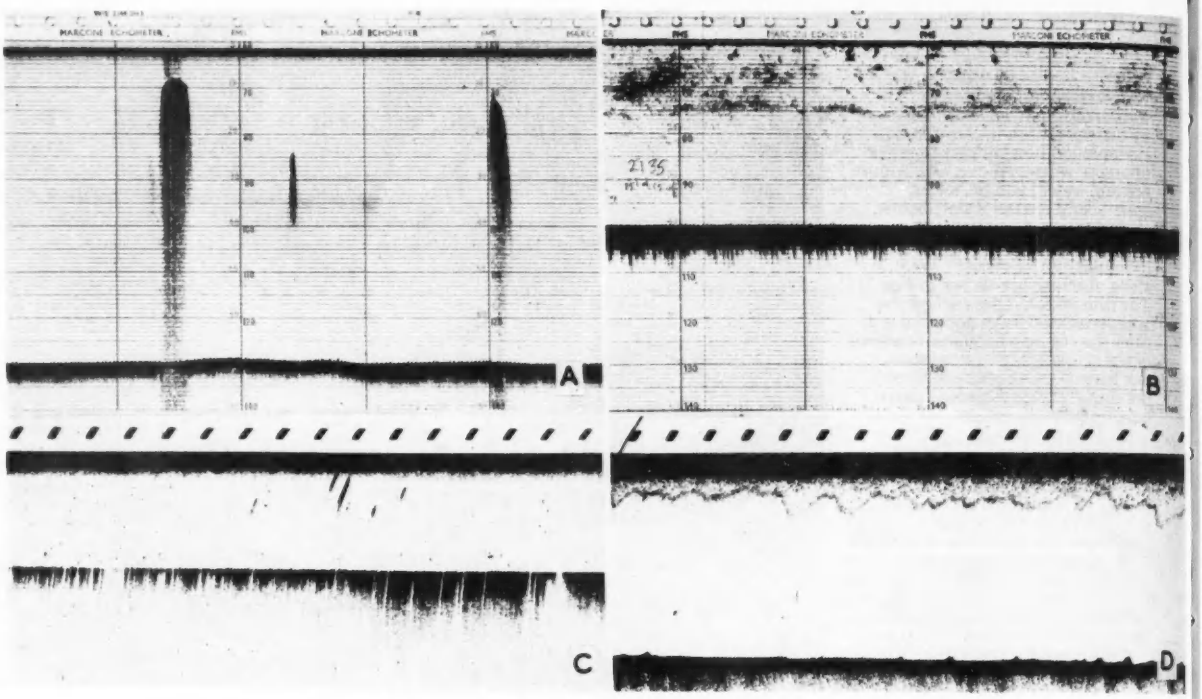


FIG. 12. Echo-sounder records from two different makes of echo-sounder. In all four records the upper thick line is caused by the outgoing sound pulse at the surface; the lower thick line is a representation of the bottom profile given by the returning echo, while intermediate traces are echoes from fish or plankton; (*a*) bottom 70 fathoms; very heavy shoals of pilchard at the entrance to the English Channel in winter. The three shoals shown are at 8, 24, and 12 fathoms, but reverberation of echoes from fish to fish causes very long "tails" to each trace well below this depth; (*b*) bottom 40 fathoms. A shallow water scattering layer at night, recorded with the ship drifting in the wind. Probably all plankton, especially the most marked layer at 15 fathoms; (*c*) more normal fish traces attributable to pilchard; English Channel, summer; bottom 40 fathoms; (*d*) shallow water scattering layer associated with a physical discontinuity. The plankton appears to have gathered after dark at the boundary between warm, light water above, and cold, heavy water below. Bottom 60 fathoms; scatter layer 11–22 fathoms, variation probably due to internal waves in the discontinuity layer. In traces (*a*), (*b*), and (*d*) the ship was steaming at full speed, and the length of record shown here represents about four miles of sea-bed and the water above.

It was at one time thought that the scattering layer was produced by a physical discontinuity in the water capable of reflecting the sound-waves. Extensive studies have been made of the phenomenon, since it has obvious practical values in protecting submarines from sonic detecting methods. In shallow water the scattering layer has on different occasions been tracked down to large numbers of macroplankton animals, or numbers of very young fish, or even, once, to very dense layers of phytoplankton. Such concentrations are often found at or near a physical discontinuity in the water. For example, in summer, when a layer of warm, less dense, water lies on top of the colder, deeper water, hence the earlier idea that it was the discontinuity itself that returned the echo.

In the ocean, the deep scattering layer appears to be caused by great numbers of shrimp-like macroplankton animals, but has also been attributed to certain types of small deep-sea fish. The concentrations of animals causing the deep scatter layer can be found beneath such seemingly unproductive areas (according to earlier theories) as the Sargasso Sea. If the deep-water plankton is taken into account, the crop of plankton in tropical seas may then approach that found in colder, more "productive" seas.

IMPROVING THE NATURAL RESOURCES

As already hinted, the easiest way to increase man's share of production from the sea would be to reduce the number of intermediate stages in the food-chain. It has been suggested that phytoplankton and/or herbivores might be used directly, and a few stalwarts have even tried eating them raw or cooked. Luckily for most of us—the taste is pretty bad—practical difficulties of harvesting prevent us using this stage direct from the sea, though some success has been claimed for pilot-scale industrial experiments on artificial culture of plants with enriched sea-water. The next stage in the food-chain, the plankton-feeding fish, offers more scope for increased exploitation, for such forms are the basis of many commercial fisheries today.

Until very recently fishery biologists thought that such forms could not be overfished. The decline in herring in the North Sea in the past few years has led to a revision of this view, but outside the North Sea, catches could be increased many times. For example, in the English Channel it was estimated that the stock of adult pilchard in 1950 amounted to approximately 100,000 *million* fish. For the same year, total English landings of this fish were about

200 tons, which represents about 0·001% of the estimated stock; if all European landings from the same area (and from the Bay of Biscay—a stock not taken into account in the calculations) are included the value is still less than 0·05% of the English Channel stock. Even the now much-reduced Clyde herring fishery has a fishing-rate of 1–3%, and many bottom-feeding fishes (cod, haddock, for example) sustain much higher proportional yields. In other words, economic considerations limit the pilchard yield, and would no doubt prevent extension of similar fisheries in other parts of the world. Nevertheless, the potential production is there when wanted.

So far no mention has been made of whales. The large species which form the basis of the present commercial "fishery" in the Antarctic are almost at the same stage in the production-cycle as the very much smaller herring and pilchard, for they feed mostly on shrimp-like macro-plankton which themselves feed mostly on phytoplankton. However, as warm-blooded mammals they are less efficient converters of organic matter than the cold-blooded fish, and their life-cycle is geared to the extreme fluctuations in plankton production that take place in high latitudes. At the moment only a small proportion of the catch is economically useful, and as there is said to be great danger of extinction of the species through excessive catching, we cannot look to this source for increased production.

The idea of farming the sea immediately brings to mind the manures and fertilisers, or their marine equivalents. Can we indeed *increase* the natural resources of the sea? According to some theories, phosphates and nitrates added to the surface of the sea (supposing they could be supplied on the gigantic scale required) would eventually be lost to deep water, and no permanent increase in production would ever be obtained. From this point of view, the only way to increase production would be to study the processes of mixing between the deeper waters and the surface layers, in order eventually to increase and control such mixing in regions supporting commercial fisheries.

But it is not at all certain that temporary or permanent increases in nutrients would increase the number of economically useful animals. War-time experiments in Scottish sea lochs, from which it was known there was no loss to deeper water outside the lochs, showed that though big increases in the fish could be obtained by adding commercial fertilisers, increases also took place in such very uneconomical animals as starfish, and the actual gain in fish was a small part of the theoretical increase in yield. Such, it is predicted, would also happen in the sea. Farming the sea would have to include full control of all nutrients *and* of the numbers of all living things present, their feeding, breeding, and migration. So close a control lies a long way in the future, for at the moment man lies at the primitive hunter stage of social organisation as far as his activities concern the sea.

At present, a short-term gain could be obtained from plankton-feeding fish. If, in the process of developing these fisheries, more research was carried out on the fish, their food, and their environment, it would ultimately help towards the immensely long-term project of full control of production in the sea.

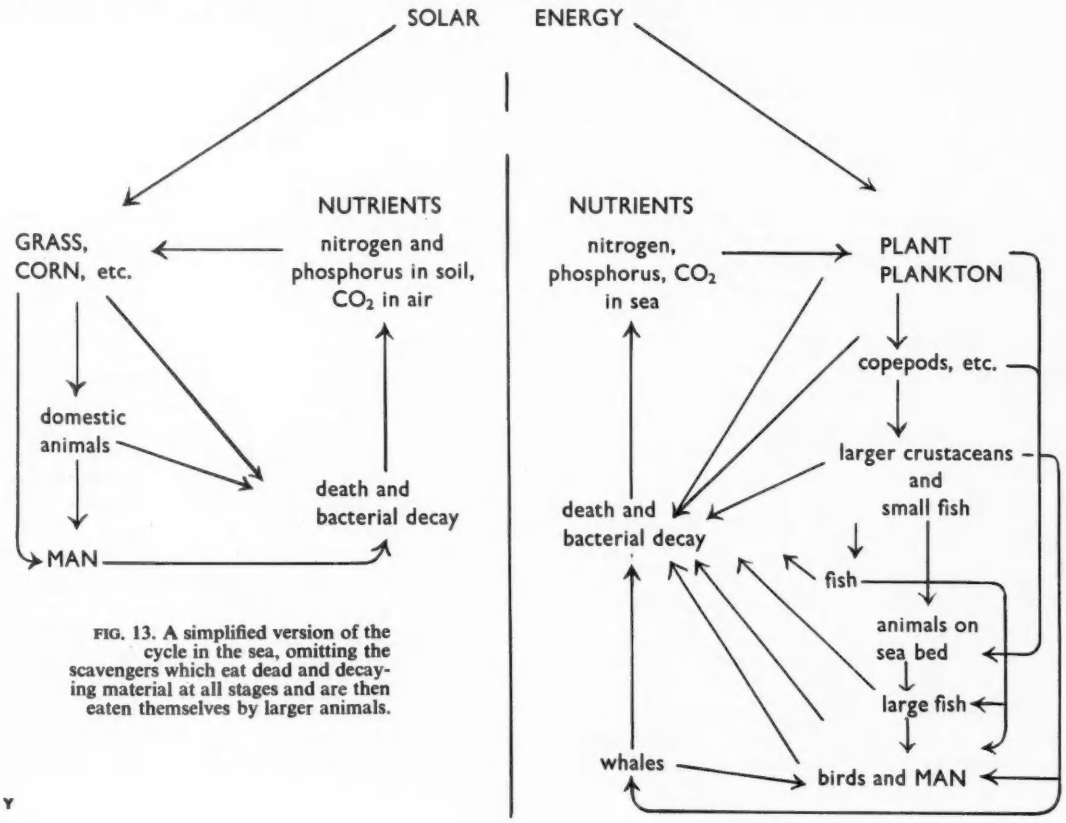


FIG. 13. A simplified version of the cycle in the sea, omitting the scavengers which eat dead and decaying material at all stages and are then eaten themselves by larger animals.

URANIUM—THE ATOMIC FUEL

D. G. DAFFORN and D. P. HAMILTON

United Kingdom Atomic Energy Authority, Springfields

In the reactor an atomic fuel undergoes changes which necessitate its withdrawal before all the fissile material has been used. As a result a cycle has been developed for the recovery of the unused fuel, the extraction of the plutonium which has been produced, and the disposal of radioactive waste.

The United Kingdom Atomic Energy Authority made history in October 1956, when Calder Hall was opened by H.M. the Queen. This was the first atomic power station to produce electricity on a commercial scale anywhere in the world, and its success was followed by the construction of a similar station at Chapelcross, Dumfriesshire, also operated by the Atomic Energy Authority. Since then, the Central Electricity Generating Board has had under construction stations at Bradwell, Berkeley and Hinkley Point, modelled broadly on Calder Hall but with greater electrical output and designed by consortia of some of the larger engineering firms in the country. The South of Scotland Electricity Board is building a further station at Hunterston, and the Central Electricity Generating Board has plans for still more at Trawsfynydd, Dungeness, and other sites.

These civil power stations are being constructed to meet the Government's programme for electricity generation using nuclear rather than fossil fuels and the Atomic Energy Authority has been charged with the task of producing the fuel elements at its Springfields Works, near Preston.

All the power stations mentioned above have reactors of the gas-cooled graphite-moderated type with natural uranium as fuel. This is derived directly from pitch-blende, a crude ore rich in uranium, or from concentrates prepared abroad from gold-field residues or low-grade ores containing a very small percentage of uranium. Refined uranium metal extracted from the raw materials is cast into rods, machined, and inserted into metal containers known as cans which are then sealed to form fuel elements for the nuclear reactors. In the reactors the fuel undergoes changes which necessitate its withdrawal before all the fissile material has been used. In consequence a cycle of processes has been developed to recover the unused fuel, to extract the plutonium which is produced, and to dispose of the radioactive waste. This article describes the production of the natural fuel elements at Springfields and refers to the other processes which constitute the fuel cycle. In addition, for the sake of completeness, a brief account is given of the principles underlying the operation of the reactors.

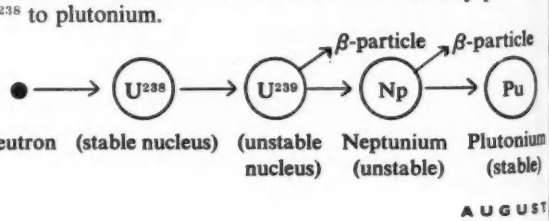
ISOTOPES AND ATOMIC ENERGY

Uranium, like many other elements, has a number of isotopes. The two commonest have atomic weights of 235 and 238, and these two isotopes occur naturally together in the proportion of approximately 0·7% U^{235} to 99·3% U^{238}. Uranium produced from the ores or concentrates by a direct chemical process contains this same proportion of the two isotopes and is, therefore, called "natural" uranium. By different processes uranium consisting of other mixtures of the isotopes can be prepared having lower or higher percentages of U^{235} and this is called "depleted" or "enriched" uranium respectively.

The two isotopes behave differently when bombarded by neutrons in a nuclear reactor. When the U^{235} nucleus absorbs a neutron it becomes unstable and splits up into two smaller nuclei. These nuclei are called the fission products. There is a great release of energy in this process and it drives the fission products apart at enormous speeds. They quickly lose their speed by colliding with neighbouring atoms, and their kinetic energy is changed to heat energy. At the same time as the fission products are formed, a few neutrons are set free and these also emerge at very high speeds. These free neutrons are available to cause other U^{235} nuclei to split and so provide the possibility of a chain action provided that sufficient U^{235} is present. With a high proportion of U^{235} atoms (that is, with an "enriched" fuel) this process could be explosively progressive and lead to an atomic explosion; with too low a proportion of U^{235} atoms the chain action would die away. By careful design such a chain action may be set up in natural uranium as in a Calder Hall type of reactor, where the process proceeds under control at a steady rate and results in a steady release of energy in the form of heat.

The heat is removed continuously from the reactor in a stream of carbon-dioxide gas which passes through heat exchangers, so producing steam for driving turbo-alternators and generating electricity as in a conventional power station.

The U^{238} nucleus also absorbs a neutron and becomes unstable, but instead of fissioning it emits beta particles and gamma radiation. As a beta particle is a negatively charged electron the loss of one alters the charge on the nucleus (or the atomic number) and the uranium atom is thus converted into an atom of a different element. In fact, the beta-emitting uranium atom becomes a neptunium atom, and this in turn becomes a plutonium atom which, like U^{235}, can undergo nuclear fission and release energy. Britain's programme for fast breeder reactors rests to a considerable extent on this conversion of the fairly plentiful U^{238} to plutonium.



THE PRODUCTION OF PURE NATURAL URANIUM

The processing of pitch-blende differs slightly from the processing of concentrates because pitch-blende contains radium and radon gas, both of which are radioactive, while the concentrates do not; but the differences arise only in the initial stages at Springfields and, as concentrates form by far the greatest proportion of the feed material, the special steps necessary to deal with pitch-blende have been omitted from the following account.

Ore concentrates, consisting of approximately 70% crude uranium oxides are prepared for the most part from low-grade uranium-bearing ores of as low as 0·1% uranium content by an ion exchange method. This method has been found particularly attractive in such countries as Canada, South Africa, and Australia for ores which are suitable for leaching with sulphuric acid.

The mined ore is crushed, leached with sulphuric acid in the presence of an oxidising agent such as sodium chlorate or manganese dioxide, and filtered to separate insoluble matter from the uranium liquor. When the uranium liquor is passed through an ion exchange system, the uranium is adsorbed on the exchange resin from which it may be subsequently removed and precipitated. The dried precipitate forms the concentrate which is the Springfields raw material.

At Springfields the concentrate is first sampled, since payment is made on its uranium content. It is then fed into large, heated, stainless-steel vessels equipped with stirrers, in which nitric acid dissolves the uranium.

$$U + 4HNO_3 \longrightarrow UO_2(NO_3)_2 + 2NO + 2H_2O$$

uranium from ore; nitric acid; uranyl nitrate; nitric oxide; steam

The resulting slurry of uranyl nitrate and impurities, both dissolved and undissolved, passes through a cooler on its way to a vacuum rotary filter, where the insoluble impurities are removed; the filtrate containing excess nitric acid can then pass forward to be freed from its dissolved impurities by a solvent extraction process.

Uranyl nitrate may be selectively dissolved in certain organic solvents; with tributyl phosphate (TBP) it forms a complex $UO_2(NO_3)_2 \cdot 2TBP$ which is soluble in kerosene. If, therefore, the impure filtrate containing the uranyl nitrate is mixed with TBP, kerosene and additional nitric acid, the uranyl nitrate will dissolve in the TBP and kerosene, and by allowing the mixture of liquids to settle, the uranyl nitrate-TBP-kerosene solution floats to the top while the nitric acid sinks to the bottom, carrying the dissolved impurities with it.

Careful plant design has enabled this process to be continuous. Impure uranyl nitrate is fed into the centre of a multi-stage mixer-settler, a solution of tributyl phosphate in kerosene is fed in at one end and nitric acid (the "strip" feed) at the other. The tributyl phosphate complexes with the uranyl nitrate, leaving most of the impurities in the excess nitric acid; any impurities which follow the uranium into the TBP-kerosene solution are subsequently washed out by the nitric acid strip feed, which flows counter-current to the TBP-kerosene, joins the excess acid from the feed stream and carries the impurities to waste.

The pure complex is next heated and mixed with a backwash of slightly acidified demineralised water in a second multi-stage mixer-settler, whereupon the uranyl nitrate transfers from the TBP solvent mixture to the water, leaving the TBP-kerosene solution to be recycled.

An insoluble yellow precipitate of ammonium diuranate is next prepared by adding ammonium hydroxide to the aqueous solution of purified uranyl nitrate.

$$2UO_2(NO_3)_2 + 6NH_4OH \longrightarrow (NH_4)_2U_2O_7 + 4NH_4NO_3 + 3H_2O$$

uranyl nitrate; ammonium hydroxide; ammonium diuranate; ammonium nitrate; water

In the Dryway process which follows precipitation, the ammonium diuranate packed in graphite trays, undergoes a three-stage conversion to uranium tetrafluoride in a reacting vessel placed in an electric furnace.

Stage 1—Roasting, or calcining—produces uranium trioxide by driving off steam and ammonia.

$$(NH_4)_2U_2O_7 \longrightarrow 2NH_3 + H_2O + 2UO_3$$

ammonium diuranate; ammonia; steam; uranium trioxide

Stage 2—Reduction of the trioxide with hydrogen—produces uranium dioxide.

$$UO_3 + H_2 \longrightarrow UO_2 + H_2O$$

hydrogen; uranium dioxide

Stage 3—Fluorination with hydrogen fluoride vapour completes the conversion to uranium tetrafluoride.

$$UO_2 + 4HF \longrightarrow UF_4 + 2H_2O$$

hydrogen fluoride; uranium tetrafluoride

As the final step in the production of pure uranium metal fine turnings of magnesium are mixed with uranium tetrafluoride from the Dryway Plant, pelleted, and the pellets fired in another electric furnace in an inert atmosphere to reduce the fluoride to uranium metal. The reaction which takes place is strongly exothermic and the temperature reached is sufficiently high to form molten uranium which runs to the base of the containing vessel where, on cooling, it is found as a billet, capped with a slag of magnesium fluoride.

$$UF_4 + 2Mg \longrightarrow U + 2MgF_2$$

magnesium fluoride (slag)

FUTURE DEVELOPMENT OF THE REFINING PROCESS

At present, all uranium tetrafluoride is produced in the Dryway plant, but a pilot plant using fluidised bed techniques has been built to supersede this plant and produce tetrafluoride more economically.

In this method concentrated uranyl nitrate solution is

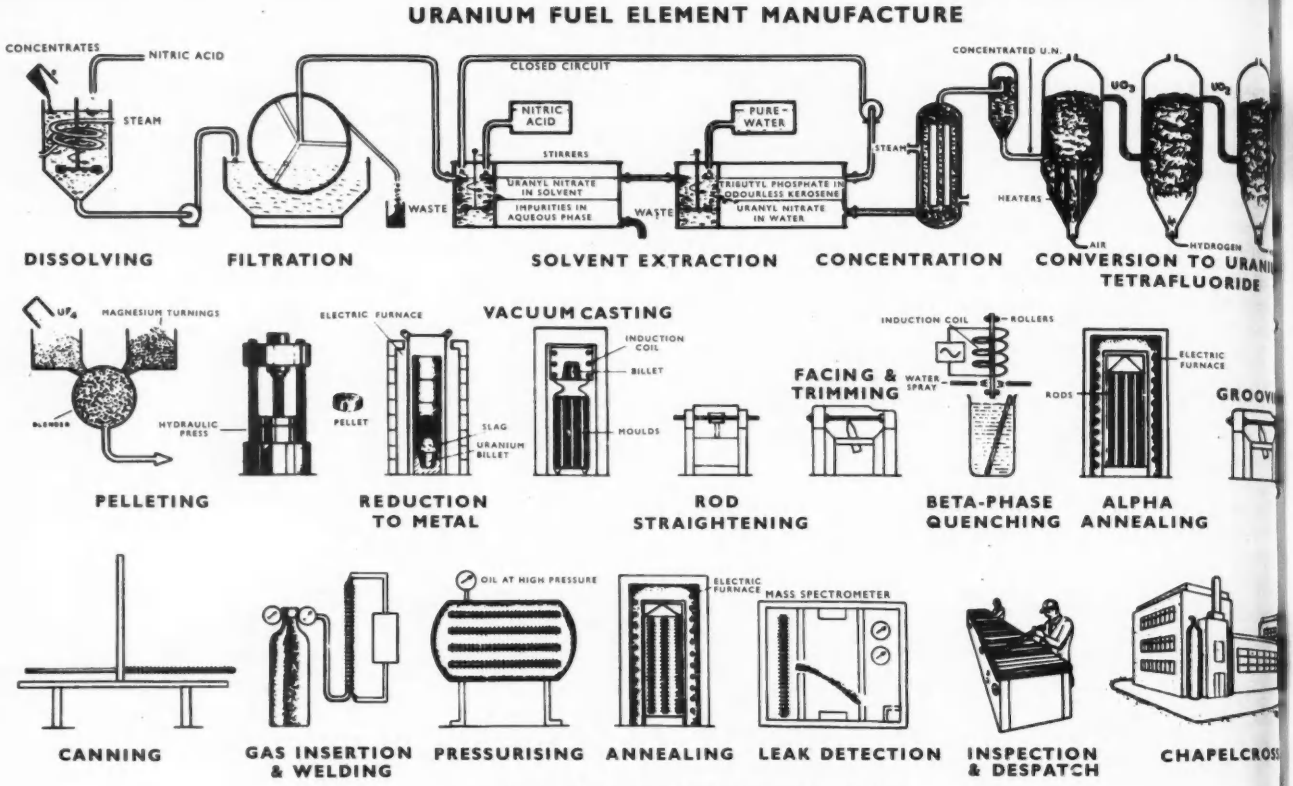


FIG. 1 (*above*). Uranium Fuel Element Manufacture.

FIG. 2. (*below*). SOLVENT EXTRACTION PROCESS.

In this process the uranyl nitrate is removed from other dissolved impurities in the solution by causing the uranyl nitrate to be taken into solution by the solvent while the impurities remain in the aqueous solution. As this part of the process is fully automatic the mixed settlers are placed in the open.

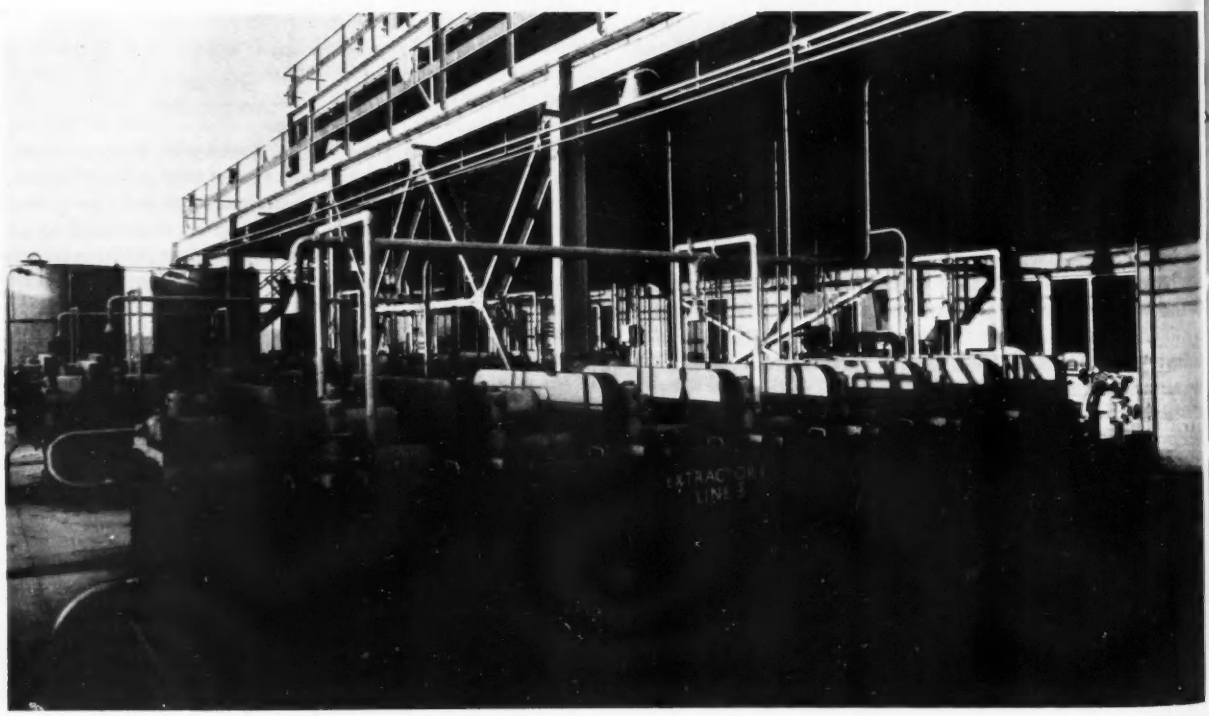


FIG. 3. MAGNESIUM REDUCTION OF URANIUM TETRAFLUORIDE TO URANIUM METAL.
One of the red-hot reactors being removed from the furnace to the cooling bay.

decomposed to form uranium trioxide powder by being sprayed into a vertical cylindrical vessel containing a bed of previously prepared uranium trioxide fluidised by a stream of hot air.

As uranium trioxide powder builds up in the reaction vessel it is continuously removed by an air stream to a hopper whence it can be gravity-fed into a second reactor where fluidisation by hydrogen carries out the reduction to uranium dioxide. Finally, in a third reactor, a stream of hydrogen fluoride gas fluidises the dioxide and completes the conversion to uranium tetrafluoride.

THE PRODUCTION OF FUEL ELEMENTS

The refining process produces a billet of pure uranium metal. To be converted into rods the billet must be melted in a vacuum induction furnace in a graphite crucible, from which the molten metal drops into a number of vertically arranged cylindrical moulds. After it has cooled, the mould assembly is dismantled and the cast rods removed, but at this stage the grain structure of the metal is unsatisfactory; the grains are too large. In order to reduce the grain size, and so reduce surface wrinkling and grain growth during the time they undergo irradiation in the reactor, they are next submitted to two heat treatment processes: quenching from the beta phase, followed by annealing. The phase change during quenching produces a fine-grained alpha-uranium structure and the annealing then releases any stresses set up in the metal as a result of this operation. On completion of the heat treatment the metal rods are machined, checked for dimensional accuracy, and rigorously inspected before being passed on for assembly into fuel elements.

A variety of fuel elements has been produced at Springfields. Those for Calder Hall, which are typical, use a fuel element can in the form of an externally finned tube fabricated from a magnesium alloy known as "Magnox". Careful cleaning of the cans is followed by a minute examination for flaws, after which the uranium rod is inserted and a cap sealed on to one end of the can using an argon arc welding technique. Evacuation of the can follows, a measured quantity of helium gas is inserted, and the second end cap is then welded into position.

Once in the reactor the fuel element will be subjected to temperature variations which would lead to differential expansion and contraction of the rod and its can. The relative movement would tend to make the can work gradually off the rod (a process known as "ratcheting") and the can would eventually fail at some point, releasing fission products and exposing the uranium to the coolant gas. To prevent this, grooves are machined into the rod prior to canning, and after the second end-cap weld the completed element is subjected to an overall external pressure to force the can into the anti-ratcheting grooves. This effectively locks can and rod together, preventing relative movement.

Finally, before leaving the assembly line the fuel element is subjected to further inspection, including x-radiography and mass spectrometer leak tests, to ensure that it will operate efficiently in the reactor without can faults developing.

THE URANIUM FUEL CYCLE

The core of a nuclear reactor of the Calder Hall type consists of a large mass of graphite built up from thousands of accurately machined bricks so shaped that vertical channels are formed in the core during building. Charge machines place the completed fuel elements into the channels and when sufficient uranium is in position the chain reaction builds up. Control is maintained at a safe level by insertion or withdrawal of rods bearing neutron-absorbing material. The control rods operate in separate vertical channels between the fuel element channels. The graphite is known as a moderator, since its main function is to slow down or moderate the speed of the neutrons ejected from the U^{235} nuclei on fission. Slower neutrons are more susceptible to capture by U^{235} nuclei, and hence the use of a moderator assists the setting up of a chain fission reaction in natural uranium and makes it unnecessary to resort to an enriched fuel. In the natural fuel some of the U^{235} atoms fission, some of the U^{238} atoms are converted to plutonium, and various radioactive elements are formed as by-products of the fission process. Plutonium is fissile, and as it is formed it tends to fission under neutron bombardment; there is, therefore, an optimum point at which the maximum possible amount of plutonium has been formed. At this stage the Calder Hall fuel elements must be withdrawn from the reactors, although only a small proportion of the U^{235} has fissioned.

The withdrawn fuel elements are dissolved in nitric acid in the chemical separation plant at Windscale, the plutonium and radioactive fission products are extracted for separate treatment, and the resulting solution of depleted uranyl nitrate is returned to Springfields. The uranyl nitrate is "depleted" because, while it still contains both U^{235} and U^{238} as nitrates, the natural balance between the isotopes has been upset by the fissioning of the U^{235} and there is now less than 0·7% of this isotope present. There has also, it is true, been a reduction in the original quantity of U^{238} since some has changed to plutonium, but the overall effect is to leave a solution of uranyl nitrate depleted in U^{235}.

At Springfields the depleted uranyl nitrate undergoes conversion to depleted uranium hexafluoride, a compound which sublimes at 56°C at normal atmospheric pressure, and this product is then transferred to Capenhurst where it is heated and fed as a gas into the gaseous diffusion plant.

The essential process at Capenhurst consists of compressing the gaseous uranium hexafluoride and allowing it to diffuse through a succession of porous membranes. The molecules of hexafluoride containing the lighter isotope are at the same temperature as those containing the heavier isotope, but because temperature is related to kinetic energy, the lighter molecules have the greater speed and therefore penetrate the porous membranes more easily. A measure of separation of the two isotopes can thus be achieved, and by employing a sufficient number of membranes in series the concentration of U^{235} atoms can be increased so as to restore the balance between U^{235} and U^{238} to its natural figure.

It will be obvious that if the process of gaseous diffusion is carried on beyond the point at which the ratio between the two isotopes is restored to the natural figure, then the mixture becomes progressively richer in U^{235}. Capenhurst

has been equipped with sufficient compression and diffusion stages to produce very highly enriched hexafluoride.

The surplus U^{238} separated from the original feed of depleted hexafluoride is "waste" to Capenhurst, but it can be re-converted to metal and used as fertile material in the fast breeder reactor at Dounreay.

From Capenhurst the restored hexafluoride can be returned to Springfields where, after conversion to ammonium diuranate, it may follow the normal route to natural (or enriched) metal. The conversion to ammonium diuranate is accomplished by dissolving the hexafluoride in distilled water to form uranyl fluoride, after which the addition of ammonium hydroxide precipitates the diuranate.

By employing this cycle the relatively scarce U^{235} may be fully used; without such a system much of it would be wasted because of the low "burn-up" of U^{235} in the reactor.

FUTURE FUEL ELEMENTS

In the civil reactors, maximum plutonium production will not be the aim; more important will be the economy obtained by achieving a higher burn-up of the fissile U^{235} before the irradiated fuel must be withdrawn. Under these conditions the life of the fuel will probably be limited by the life of the can because as the fuel rod suffers physical damage (swelling and cracking) due to the formation of pockets of radioactive gases within the rod, the can also becomes distorted. If the distortion is sufficiently severe the can will fracture and allow radioactive fission products to escape into the coolant gas stream, at the same time exposing the rod to the effects of the gas. Obviously, therefore, there is a demand for metallurgical research on canning materials.

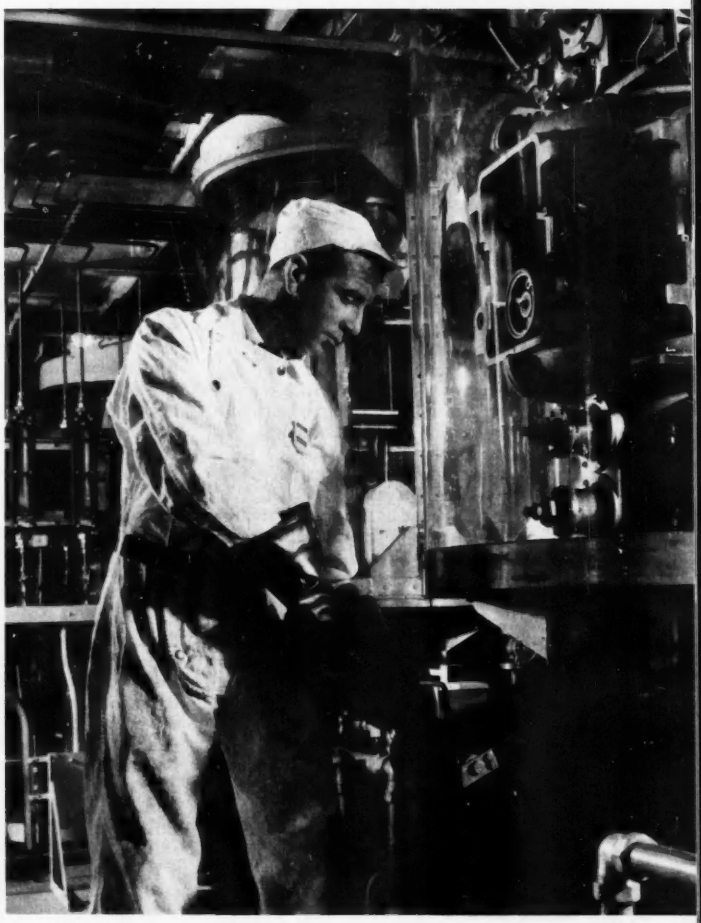
There are other possible types of reactor besides the Calder Hall type; one of the promising variations will use fuel elements composed of compressed, sintered, uranium oxide pellets encased in stainless steel or beryllium cans, and these should be able to operate at temperatures considerably higher than those imposed in Calder Hall. Higher temperatures will mean higher quality steam for the turbo-generators and greater overall efficiency. Much research effort is being deployed also on this project.

Springfields has produced several different types of element in the past, future commitments are heavy and each fresh variation produces its own problems, so that it is obvious that in the fields of both research and production fuel elements will provide a most interesting challenge to the Atomic Energy Authority's staff for several years.

FIG. 4 (*right*). FUEL ELEMENT FABRICATION LINE. Beta-quench apparatus. A uranium rod being removed after receiving heat treatment designed to reduce the grain size of the uranium metal.

FIG. 5 (*below*). FUEL ELEMENT FABRICATION LINE. Cast Rod Bond Store. In this room cast rods of uranium are stored temporarily as received from the vacuum casting line before proceeding to machine line.

(All illustrations by courtesy of U.K. Atomic Energy Authority)



This essay is presented by Associated Electrical Industries Limited to mark the Tercentenary of the Royal Society

SCIENCE AND SOCIETY

This unbreakable continuity which begins as a page of mathematics . . . or an experiment in a laboratory and ends (if it can ever be said to end) in the happiness or despair of men and women.

UNDER the heavy blackness of a Nigerian evening a dozen Africans are peering through a hedge. Their faces are alight with excitement. They watch in astonished silence. Beyond the hedge is the verandah of a private house and on the verandah a ghost-white image on a television screen.

A mile away, in a busy thoroughfare, African boys sit in clusters under the street lamps. They are studying for School Certificate. They have to do their homework in the street, for there is no light at home except a candle in the corner of the room.

These scenes epitomize the impact of the electrical industry on civilization. To catch the drama of it in 1960 one has to go to countries like Africa and India, but in 1860 the drama was being played in Europe. That was the time of the cable-laying boom; Londoners still marvelled at the fact that messages could be sent instantaneously from England to France, and two young engineers, WERNER and WILLIAM SIEMENS, were planning a cable (the plan was fulfilled eleven years later) to link Europe with India.

Instantaneous communication: this is the paramount contribution which electrical engineers are making to the world. Power is carried instantaneously from waterfalls to cities. Messages are carried from one continent to another. Ideas are carried to television screens in millions of homes. The power is put to work in a steel plant, an X-ray therapy apparatus, a reading lamp over a desk. The messages pledge a contract and announce an election and break a heart. The television screens display a crooner, a Western, a smart young man reading the news.

Europeans have had little more than a century to adjust themselves to the shock of instantaneous communication and the shock is only now reaching millions in Africa and Asia, destroying centuries of tradition, driving society at a fresh pace. It is not sufficient to understand the technology which causes the shock: the shock itself must be understood too.

A technological achievement does not stand by itself. It can be understood only if it is regarded in the context of its history. It stretches back through salesmanship, production, design, to the scientific work which made the achievement possible; it reaches forward into social and economic changes which follow the achievement. Technologists in the steam age were not fully aware of this unbreakable continuity which begins as a page of mathematics in a notebook or an experiment in a laboratory and ends (if it can be said ever to end) in the happiness or despair of men and women. In the electrical age technologists have become aware of this continuity; they realize they cannot confine their interest to technology. They know that every achievement in the electrical industry is inseparable from the science out of which it grew and the society in which it will bear fruit. A factory making electric generators, for example, cannot be understood in isolation. Its activity begins in schools and technical colleges and university laboratories, where ideas germinate and interests are formed, and its influence can be followed after the generators are installed: into Indian villages, emancipating the people from poverty and dissolving the constraints of caste; into the minds of Africans, detribalizing them and moulding their ideas into patterns of the twentieth century; into the Arab world, equipping it with tools for its resurgent nationalism; into the industrial towns of Britain, creating new opportunities for employment and new conditions for family life. It is no wonder that industry has become one of the patrons of learning. The technologist is irrevocably involved in mankind.

Of course, this is no sentimental involvement, no woolly gesture of good will toward boffins and sociologists. In the electrical industry it is a hard-headed recognition of two facts: the first, that technology draws its nourishment from three hundred years of scientific thought; the second, that the achievements of technology change men's minds, and that it is essential that these changes should be understood.

ROBERT BOYLE'S LEGACY

Consider an example which illustrates one of the implications of electro-technology. The moment when a dozen Africans saw a television programme for the first time was the consummation of a process which started in the year when the Royal Society was founded, and which will continue into an unfathomable future. Television screens, like X-ray tubes, radio valves, cyclotrons, and electron microscopes, require high vacua. Only in the last thirty years has it become practicable to make really high vacua, but this comparatively recent achievement would have been impossible without three hundred years of endowment from Western scientist. The chief legacy, perhaps, is from ROBERT BOYLE. At a country house in Beaconsfield, exactly three hundred years ago, BOYLE wrote an essay, in the form of a letter to his nephew, on the properties of a vacuum. He called it "the spring of the air". In it he describes one of the earliest vacuum pumps, but the importance of his essay lies not in a technique but in a leap of imagination. BOYLE helped to strip off the mystical jargon which had surrounded the idea of a vacuum since the time of ARISTOTLE, and he substituted what the first historian of the Royal Society called "positive expressions, clear senses . . . bringing all things as near to Mathematical plainness as they can". BOYLE's essay is leisurely and discursive. Few technologists could be bothered to read it to-day. At the time he wrote it the relevance to industry lay concealed nearly three centuries beyond the imagination of his contemporaries. But when technologists needed to understand the properties of a vacuum there was awaiting them a legacy of nearly three centuries of research. It can truly be said that BOYLE's thought is one of the scientific ingredients of a television set.

BOYLE's work is only one example—and a comparatively unfamiliar one—of the massive foundation of science which underlies the electrical industry. Even less familiar examples could be found, for instance, in the work of botanists who germinated seeds of the rubber tree at Kew, to be used to start plantations in Malaya: an episode which assured the electrical industry of a supply of insulating covers for cables. And the familiar names—FARADAY and HERTZ and RUTHERFORD, for instance—are now revered among the patron saints of technology; their relevance is indeed so obvious that it would seem impossible to overlook the young Faradays and Rutherfords who may be working in laboratories to-day. But they could easily be overlooked, for to-day's Faradays and Rutherfords are working at problems which have no foreseeable application to technology. There is no way to predict the significance of their work to the technologies of fifty years hence. Accordingly, industry supports science for its own sake in the belief that all science is potentially relevant to technology, and that modern industry must breathe the very atmosphere of science.

THE LEAP OF IMAGINATION

To a man whose life is spent among practical things it is a surprising atmosphere, this atmosphere of science. The popular impression of how a scientist works is very far from the truth. Science fiction would have us believe that the scientist is a passive recorder of facts. As BRONOWSKI once put it, scientists are pictured as "going off to work in the morning . . . in a neutral, unexposed state. Then they expose themselves like a photographic plate. And then in the dark room or laboratory they develop the image . . ." and some new formula appears. The unexpected truth about scientists is that their tools of trade are abstractions, symbols, and imagination. The abstractions are indeed derived from observations and checked against observations, but the essence of scientific thinking is abstraction from reality, the leap upstream, the symbol. To have watched FARADAY at work, fixing a magnet inside a coil of wire, would have given no inkling of his genius. His unique contribution to science was a leap of imagination: to conceive a field of force between the wire and the magnet. A field of force has no material basis: "What this state is", he wrote, "cannot yet be declared." But this did not matter. As soon as he began to think, wire and magnet were forgotten: FARADAY entered a world of abstraction. "The mutual relation of electricity, magnetism, and motion", he wrote, "may be represented by three lines at right angles to each other . . ." Sheer symbolism; and from this symbol stems the London Underground, the Kariba dam, and the beautiful fabric of field physics.

The purpose of science is to understand Nature, but science works by picking out abstractions from Nature (shape from a crystal, pressure from a gas, resistance from a wire) and transforming them into symbols. These symbols, products of a disciplined imagination, became powerful weapons for the conquest of Nature. The realities of science are concepts: not wire and magnet but current and electromotive force; not glassware and pumps but

pressure and volume. The scientist's creed is a paradox: that without symbols reality is out of reach. No wonder industry did not immediately take to science: a scientist's pattern of thought is so much like a poet's.

PACE-MAKER IN SCIENCE

Imagination in science has constantly to be disciplined. Every fresh abstraction has to be referred back to Nature and if it is inconsistent with Nature it is jettisoned. This involves experiment, and experiment involves technical skill. As science becomes more subtle this reference back to Nature becomes more difficult. The progress of science may be held up for years because apparatus cannot be devised to make the observations necessary to check an abstraction. It is at this stage that industry comes to the aid of science. Science and industry are now allies and history has proved that this alliance is as necessary for science as it is for industry. Indeed technology is often the pace-maker for scientific advance. In the nineteenth century, for example, the pace of research into the structure of animal and plant cells was set by the firms which designed microscopes. More recently the production of an electron microscope may be regarded as a major contribution to scientific thought. In biology alone it has opened up a new and fantastic world of the infinitely small; it has already illuminated subjects as diverse as human heredity and the synthesis of sugar in leaves. Perhaps the most vivid example of the contribution which industry can make to science comes from the experimental verification of the most important equation in history: EINSTEIN's $E=mc^2$. These symbols represent a tremendous leap upstream of scientific thought; they assert that if mass were turned into energy the amount of energy would be equal to the mass multiplied by an astronomical figure, the square of the velocity of light. To test this it was necessary to smash an atom. Two Cambridge physicists, COCKCROFT and WALTON, devised a way to do this (by directing a stream of protons against a film of lithium); but the equipment for the experiment could not conveniently be made in a university laboratory. The electrical industry came to their help. The success of their experiment is a vivid example of the pattern of partnership in modern scientific discovery: it is a fabric woven of symbolism and imagination on the one hand and the resources of industry on the other.

THE SOCIAL FRUITS

Technology has its roots in science. Its fruits are in the lives of men and women. For some years industry has recognised its responsibility toward research in science and mathematics, forerunners of the machine. More slowly, and with some misgivings, industry is now coming to realise that its responsibility does not end with making, installing, and servicing the machine; it has some sort of responsibility—still to be defined—toward research on the consequences of the machine and its influence on society.

This responsibility has to be focussed before it can be defined. It is in the under-developed countries that it comes most clearly into focus. In India (for example) there are still some half a million towns and villages without electric light or power. Millions of the people of India still measure power by the amount a man can lift or a bullock can pull. The roads, lined with banyan trees red with dust, still carry an endless procession, as they have for a thousand years: people walking, silent, barefoot, with burdens on their heads; the women in saris of yellow or scarlet, the men with white cotton dhotis tucked into their waists, bearing brass water jugs, six-foot bundles of sugar cane, baskets of chickens. And suddenly the technological revolution has swept across this ancient civilisation. Little naked children running about the streets will soon take for granted steel mills, factories making transformers, electric light, radio. The massive five-year plans of the Indian Government will, in one generation, dissolve away centuries of custom and tradition. Since 1949, to take one example, a hydro-electric plant on the Cauvery River has poured hundreds of megawatts of power into Madras. The industrialist is familiar with the research and development which have flowed into the generators and switchgear of this hydro-electric station; he can trace the stream of thought back to its source among the physicists of the nineteenth century. But he has not yet spent much time following the stream forward into the Indian villages, into the minds of men who are accustomed only to the slow movements of cattle and the imperceptible growth of crops. Consider NAYAN SUBBARAM and his family, who live in an Indian village and make a living by weaving *khadi* on a foot-loom: what will happen to his household when electricity comes to his village, bringing light, radio, and a cinema? Can he and his neighbours be helped to cross in one generation a bridge which the British people spent over a century in crossing? Not enough is known to answer these questions, yet it is as important to study the impact of technology on NAYAN SUBBARAM as it is to study the impact of science on technology. Industry, already concerned with problems in physical science which precede the machine, is inevitably becoming concerned with problems in human science which follow from the machine.

There is, however, a serious difficulty. By the time the physical sciences attracted the attention of industry they were already mature, sophisticated, professionalised, with nearly two centuries of achievement behind them. The human sciences are still naive and groping. Nevertheless, pioneers in this field must be encouraged; among them may be men who will do for the human sciences what BOYLE did for pneumatics. For some time to come, studies on the influence of technology on society are more likely to earn the respect and support of industry if they are modest in scope, specific in intention, and tentative in conclusion. There is plenty of opportunity for such studies as these; without them, technologists will never comprehend the full sweep of their subject.

This full sweep can already be discerned dimly in one recent episode in electro-technology: the production of the transistor. In 1897 HALL did some simple experiments which enabled him to calculate the mobility of electrons in a conductor. At the time the experiments had no conceivable relevance to industry. Years later the HALL effect (as it was called) was taken up and applied to the behaviour of electric currents in a semi-conductor, the rare element germanium, which is extracted from the flues of gas works. The result is common knowledge: in 1948 it was announced that transistors, made from germanium, could take the place of radio valves. They had three immense advantages: they used much less current, they occupied much less space, and they lasted much longer. Already the transistor has set up waves in society which are travelling in many directions. It is essential for information-equipment in rockets; it exposes new horizons in those branches of applied mathematics which require large electronic computors; it has made possible the pocket radio receiver, which runs for months on a four-volt battery.

The transistor is likely to work a revolution in the developing countries of the world; for radio receivers which run from the mains, or even from accummulators, are out of the question in a town where there is no electricity, whereas a radio receiver which needs no attention beyond the replacement of one dry battery once or twice a year is quite practicable. It could, for example, bring some 60 million people in tropical Africa in touch with the Western world. As the tribes of Nigeria and Ghana coalesce into nationhood, it is the transistor radio which will draw them together, unite them to their leaders, and preserve among them a common tongue. Through broadcasting studios and power stations the electrical industry has created new nerve centres for the nations.

It is for reasons such as this that industry is involved in the whole sweep of discovery, from pure mathematics to sociology. It is involved, too, in education, which is the technique for transmitting human experience from one generation to the next. Indeed industry is itself partaking on a massive scale in the education of technicians and technologists. Through technical education in Germany in the nineteenth century, wrote WERNER SIEMENS in 1874, "thousands of co-workers in science . . . have sprung up". For fifty years and more the electrical industry has produced its own co-workers in science through schemes of apprenticeship training; and in doing so new techniques of teaching have been devised and (more important still) unexpected potentialities of skill have been discovered in quite ordinary men and women. Modern apprenticeship-training schemes have improved the "trainability" of man. A few years ago it could have been said that the rate of learning had not improved since PLATO taught in the Academy. This is no longer true; and the demonstration that even the ancient technology of teaching can be made more efficient is one of the contributions which industry has made to learning.

Technology faces its implications. The whole spectrum of human enquiry, from the symbolism of the mathematician to the case histories of the social worker, illuminates the design and manufacture of a machine. Technological achievement is one instant in a process which begins at the sources of science and flows until it joins the tides of society.

E. A.

July 1960.

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AEI

SCIENTIFIC AND EDUCATIONAL TELEVISION IN THE U.S.A.

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As the number of school-children and university students in the United States increases, the number of teachers declines. The result has been a variety of experiments in education by television.

An extensive tour made recently in the eastern region of the U.S.A. gave the author the opportunity to study the part played by television in education. Two quite distinctive developments have taken place. The one exploits the closed circuit and is used essentially at the moment as part of university teaching technique, the other uses the national open broadcast networks, either exploiting the commercial transmitters or making use of special transmitters run, for instance, by some of the universities. Teaching by television, and the teaching of science plays a prominent part, has become a subject for intensive university research which is sponsored by the Ford Foundation and by other bodies. In the latest report of the Ford Foundation it has been made clear that remarkable developments are taking place. No fewer than twenty-five colleges and universities, 100 schools, and 100,000 students are actively engaged in what might be called television experiments. There is, in addition, a considerable early morning popular audience as well as the tied audiences in schools and colleges.

The exploitation of television in American education has been largely stimulated by the increased birth-rate. The number of births has risen by 50% since the end of the war and is now 4 million a year. At the same time the number of aspirant teachers is less than the rate of retirement. The number of new university teachers qualified with a Ph.D or a M.Sc. is steadily falling. There has then arisen a demand to exploit more effectively the good teachers, and television is offered as one answer. There are 50 million television receivers in the U.S.A., indeed a survey shows that more homes have television than have baths.

The Federal Communications Commission has set aside no fewer than 250 wavelength channels for educational purposes. There are now 39 open educational stations in operation and 150 closed-circuit installations in schools and colleges, plus 21 closed circuits for training in military establishments. Enough has been already achieved to enable critical assessments to be made.

KINDS OF TELEVISION

Curiously enough, teaching by television in the U.S.A. has been placed on a materialistic, practical basis. American students are obliged to collect "credits", that is, a number of required courses are insisted upon and attendance is compulsory. Many of the televised courses are also valid for credits, in a manner to be explained later. The army and the medical schools were quick to realise that TV screens suitably distributed in a large classroom gave a "front-row" seat to every student and complex operations could be shown enlarged close up.

The number of institutions offering credits for prepared television courses is remarkable. No fewer than 117 colleges and universities offer TV courses for credit. In addition, 250 colleges accept viewing-in at 6 a.m. courses (home viewing, of course) for credits. Furthermore, almost 600 school districts, clustered into some ten regions, make regular use of televised instruction. It is estimated that well over half a million school and college students partake. Of course, since stations are local and of small range, there is vast variability in subject and in quality.

A primary stated aim has been to bring superior lecturers and teachers to a vast audience, and a second object has been to bring to students a very wide range of experiences, such as, for example, seeing and hearing a distinguished national poet reading his own poetry. A dominant activating concept is that television is not a teacher, but only a conveyer of teaching, the man before the camera, rightly so, is the principal factor.

A good deal of money has been spent on research to determine the potentialities. At many universities, where we have seen the closed system at work, first- and second-year students (the numbers are formidably large) receive instruction on the closed circuit. In one district, forty schools are tied to a closed circuit and the children are taught by this method, 18,000 receiving the instruction.

All this is tied television, the audience is more or less captive, but there is another audience, a curious one. The National Broadcasting Company (NBC) has a nation-wide network of stations, and six times a week, at the unearthly hour of 6 a.m., courses in both modern atomic physics and in chemistry are put out, under a title "Continental Classroom". It is estimated that this has an audience of no less than 270,000, mainly high-school teachers, college students, and the inevitable housewife who, the Americans tell us, hungers for culture.

One of the statistical studies carried out at Pennsylvania State University claims to have established, by running courses in parallel both live and televised, that there is no significant difference in achievement in examinations. The classes (200 or more) are big enough to give a fair statistic. This finding has, in fact, surprised the sponsors of the project, for it is pointed out that the rooms employed were not designed for televised instruction; nevertheless, the improvisation has functioned splendidly. Since hand-picked teachers are used to televise, and since "studio" teachers combine and team up with "classroom" teachers in

FIG. 1 (*above*). The use of projection television in a university auditorium during a simple chemical demonstration.

FIG. 2 (*right*). Television through the microscope being used in a zoological demonstration.

preparing, material, it is really believed that the students are far more stimulated than they would have been by the average, good, pedestrian teacher. Indeed, as far as schools go, it is being claimed that television teaching is better than school-teaching, largely because of the woeful supply shortage of good school-teachers. Thus it is felt that while there is at least no loss in the universities, there is definite gain in the schools. The balance in favour of improved results in schools is claimed as a percentage ratio of 62 : 38. Of course, viewed critically, this may not be a measure of the good television, it may be a measure of bad school-teaching.

FIG. 3. A small class using standard black and white television to receive a demonstration of a dissection.

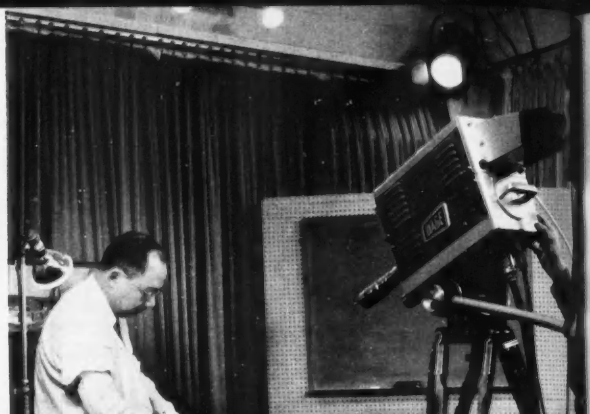

FIG. 4. A simple studio set-up to transmit the demonstration dissection.

TELEVISION AND THE SCHOOLS

Television teaching relieves the burden in school-teaching. The classroom teacher views-in too, but he is freed from the considerable burden of preparing his lesson. All he needs is the pamphlet supplied by the broadcaster and then his teaching job is to exploit the stimulus of the broadcast, after it is over, although, of course, he has also to prepare his class to receive the broadcast. An essential part of the scheme is stated to be the desirability for conference between studio teacher and class teacher, but one wonders how this can at all be achieved, it sounds a pipe-dream.

Of some considerable significance is the reported claim that young and not very experienced teachers have themselves learnt new techniques in teaching, especially in laboratory demonstrations, by watching the methods of experts on television. It is recognised that timetable difficulties need to be overcome, and it is still customary to use half-hour broadcast periods. It is of curious interest to report that there has been a good deal of resistance from many *university* teachers. Some are contemptuous, others really fear an economic impact, in that a few internationally known good teachers will tend in the long run to displace others and make them redundant. Conversations with university teachers confirm the fact that these fears have not yet been dispelled. So far there does not appear to be a like resistance from school-teachers.

HAGERSTOWN EXPERIMENT

In the schools, receiving classes are sometimes as big as 160, convening in a large auditorium with several television sets, or alternatively splitting into several groups of forty each and meeting in separate rooms. Controls and tests of achievement are really too difficult to carry through in the schools. The largest experiment, at Hagerstown, Maryland, has been running four years now, and the aim is to provide an improved education service for 18,000 children without increasing normal costs. This small region has become a model showpiece to which students, teachers, and educational administrators flock in their thousands. Classes are deliberately large, up to 120, and a closed-circuit system is employed. Subjects cover the whole school range, first to twelfth grade, including art, music, number, reading, arithmetic, social studies, science, geography, practical arts, mathematics, geometry, physics, history, English. All the forty-eight schools in the administrative area are tied to the programme, something which showed much initiative and courage, for the area covers 460 sq. miles. The closed system has electronic advantages and can take six scrambled broadcasts simultaneously. These are unscrambled and can be used simultaneously in different schools or different classrooms. The "studio" is an improvised corrugated metal shed.

The opinions of the teachers have been consistently considered in arranging the broadcasts and every teacher has been polled for his or her opinions. A planning committee of the teachers themselves has organised the programmes, and how much better this is than our system of lessons imposed by BBC or ITV producers. The upshot of the study has been to delegate responsibilities between studio teacher and class teacher: the one to stimulate, the other to drill and to develop the material. After telecasting, "feedback" sheets and regular meetings constantly correct unwished-for tendencies.

That the teaching has improved over the past four years is the considered opinion of the sponsors of the experiment, especially since it is a rural area without access to very many specialist teachers. There has been a statistically significant improvement in arithmetic. In the secondary schools the children collect in the auditorium around a number of television sets. Each receiver has two monitors: a secretary and an "engineer" whose job it is to adjust the receiver, a simple matter, but one calling for a monitor.

THE CLOSED CIRCUIT IN SCHOOLS AND UNIVERSITIES

The cost of covering 460 sq. miles of country with a closed circuit is fairly formidable and the figure of £300,000 has been quoted for capital value of equipment and cables. A similar sum has been spent over four years for staffing, maintenance, and experimental charges. This latter sum, however, includes salaries of twenty-five studio teachers and also an administrative and engineering staff of nearly fifty more. If costs can be kept below £120,000 a year, the system will pay for itself.

The teacher in the classroom has five minutes to prepare the class on what it is to see. Broadcasting lasts twenty minutes and then the lesson is discussed. A teacher is always present during the broadcast. It is emphasised that television occupies but a small fraction of the total instruction received per day. Many problems have emerged. Facilities are as yet inadequate; studio teachers are hard to find. Classroom teachers require some training in the newer technique, pupils have to learn the new approach, and, most difficult of all, the problem of the varying ability of pupils, serious in any classroom, becomes formidable when the class numbers many thousands.

So far it appears that the advances in university television techniques are ahead of those in the schools. The author has been able to examine at first hand the operation of a fully active system at the Pennsylvania State University, a system ably developed by L. P. Greenhill, formerly of the University of Melbourne. Here, too, action has been prompted by the increasing number of students (15,000 in a university is typical in the U.S.A.). Some additional advantages are that demonstrations can be presented in high magnification close-up so that members of the class see very much more than in the normal lecture theatre. Even the close-up of the teacher's face is considered a considerable advantage. In close-up, all irrelevant material can be discarded and this assists concentration, something not possible usually in a live class.

A systematic study over four years has been made at Pennsylvania and now some 4000 out of the 14,000 students at the university attend some of the internal television courses, of which thirteen are given over the closed circuit. In the earlier experiments the camera was brought right into the classroom. This was, in fact, not advantageous for several reasons. The cameras could not be moved and turned round. Too strong a lighting is needed for the participating class. Progressively fewer students were used in the broadcasting room until ultimately they were abolished and a proper studio, free from class influences, was adopted. It was found that with a class in front of him the teacher tends to ignore the outside audience and speaks only to those before him. In addition, the students outside the studio felt they were only getting second best, so on these and other grounds there was a natural drift to separation of class and studio.

The formidable problem of "feedback", the intercommunication between teacher and class, has only been partially solved. To begin with, in each room sits an assistant teacher, usually a post-graduate research worker. He acts as supervisor, distributes, when necessary, printed matter, and helps with the feedback communication system. Each room has a separate speaker and microphone linked to the teacher in the studio, who also controls a red light. The teacher can ask questions and students raise their hand to reply, the assistant picks one, and when the red light goes on, he replies; this is heard by teacher and by all classrooms. Thus some discussion is possible, even if the teacher does not see his pupils. Two-way camera communication between teacher and pupils has been tried, but was ineffectual and was dropped.

A course in elementary mathematics involves classes of more than sixty students each with an experienced television lecturer in the studio. The author quietly stepped into one of the classrooms. Large 24-in. receivers were above eye-level. No student was more than 24 ft. from a screen (up to six vision receivers are used in one room). Sound came from a single loud-speaker high up in a ceiling corner. Despite full room lighting, the brilliance of the receivers was adequate. At critical times in the discourse the supervisor (who also checks the register) distributed notes, graph paper, and work sheets.

The atmosphere was certainly not that of a classroom. Students talked to each other in undertones, causing some disturbance, and late arrivals were common. They just drifted in. Two techniques in the studio were used, either prepared sheets (with worked-out algebraic formulae) were shown in close-up, or else the teacher was shown working at the blackboard. There was an air of restlessness usually absent in the live class, but the pace was what would be normally expected from an experienced teacher, and the note-taking was at the familiar speed.

The author then visited the production room. It was surprisingly simple. It housed only one technician, a power-pack system, and three monitor tubes operating from three cameras in the studio. The crew in the studio was astonishingly small. Two youngsters operating two cameras and no one else. No producer, no floor manager, no sound expert, no lighting expert, no boom microphone operator, no secretaries, in fact none of the fantastic crew crowded into the usual professional broadcasting studio.

An ordinary classroom was used, and the lighting was simple and mild. The teacher just lectured to the empty room as he would to a class, carrying a neck microphone so that his voice remained uniform even when he turned to the board. Some classes need students present as part of the teaching demonstration, and in such cases no fuss is made about lighting or special arrangements.

An inquiry into the cost of the system reveals that the cameras, power packs, mixing unit, monitors, and several receivers cost no more than £5000, a surprisingly low figure. This is due to the introduction of the cheap, new Vidicon-type television camera.

An analysis of the costs of televised courses show that a gain is reached as soon as the class exceeds 200.

NATIONWIDE SCIENCE BROADCASTING

On U.S.A. television there is virtually nothing resembling our magazine science programmes here, but there is something a good deal more striking. The commercial companies have offered free broadcasting time between

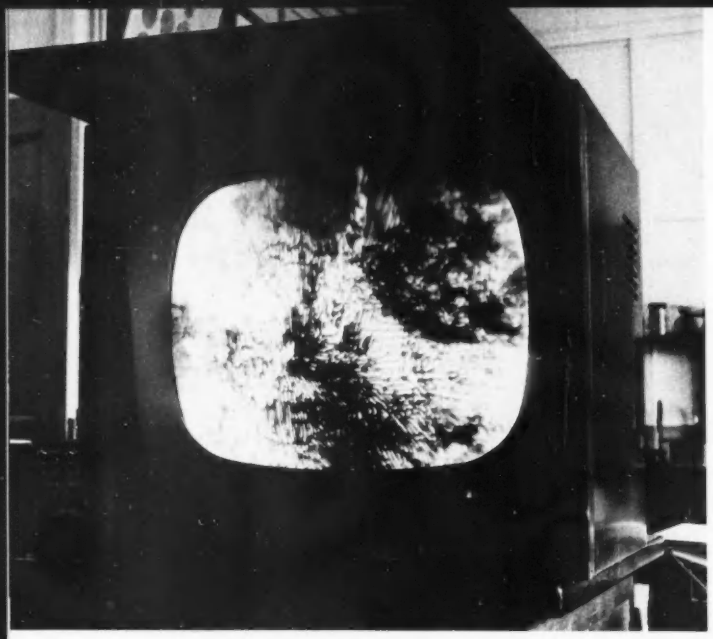

FIG. 5. The value of television to enlarge a picture in the microscope, is demonstrated in this metallurgical specimen projected to an audience.
All illustrations kindly supplied by the Division of Academic Research and Services, Pennsylvania State University.

6 and 7 a.m., and this has been accepted and exploited for the broadcast of university science. The first of such courses was the "Sunrise Semester" offered by New York University in the New York metropolitan area. This was an astonishing innovation, for it offered credits, and by the end of the first year 1500 students had enrolled for credit, while an additional daily audience of 100,000 was estimated, despite the appallingly early hour.

Chicago City Junior College has gone a step farther, broadcasting over forty hours of college courses a week, such that "extension students" receive enough material to earn an Associate in Arts diploma entirely by television, thirteen courses being broadcast by what is popularly called the "Chicago TV College".

Television students must first have the usual entrance requirements to the college and buy prepared study guides. At Chicago the courses are broadcast during the day and repeated at night on a privately owned station. Exercises in the study guide are to be worked and sent by post to the college, corrected material being returned. The student can report to his teachers for guidance up to three times a term. Remarkable is the fact that the studio teacher and the teachers who mark the papers are available on the telephone at scheduled times to answer student queries. In due course the college sets examinations. At the end of the first year 7000 students had registered, 1500 having enrolled for credit courses. After four years' working, it has been found that the extension students were the equals in attainment with the internal students. Analysis shows that they are mainly women between their twenties and forties, one-quarter of whom had already completed a year at college. It was a more mature and more able student body than that normally attending the day courses. Their stronger motivation more than compensated the lack of personal contact.

This Chicago example is spreading and is expected to become important. However, by far the most outstanding broadcast is the nation-wide "Continental Classroom". This was first launched in the autumn of 1958 and was, it seems, directly stimulated by the space-satellite race. It was decided to attempt to improve the status of physics teachers already in employ. The course was given daily during the academic year, being directly administered by the distinguished physics teacher H. E. White, Professor of Physics at California University. This has had a surprising impact.

No fewer than 250 colleges and universities are offering credits for the early morning courses and they are now being given in physics and chemistry at 6 a.m. and 6.30 a.m. respectively.

The scheme is sponsored by NBC, the American Association of Colleges for Teacher Education and the Ford Foundation. Substantial financial support comes from several large industrial organisations.

Not every state radio station accepts every programme, but the author was able to view one, at 6.30, a chemistry broadcast arranged by Dr J. F. Baxter of the University of Florida.

CONTINENTAL CLASSROOM BROADCAST

The broadcast began in a manner strange to our ears. The lecturer was introduced by a long biographical note. In succession were quoted, first his degrees, then his publications in science, followed by his standing as an administrator, and finally his present position. The lesson, number 108 in a series, started off with co-ordination compounds and their valency characteristics. The lecturer moved smoothly from board to board (he seems to have had a large number at his disposal, but since video tape was being used this may have been an effect of editing). It was typically good, smooth continuous university lecturing by a mature teacher who was a thorough master of his job. It was certainly not easy going for the uninitiated. The impression was that it was something like a second-year general degree course here. It was fast and perhaps a little superficial but not unduly so. A discourse on dissociation constants of amino acids and stabilities of five- and six-membered rings occupied the main time. Practical applications were brought in and the material was of very real interest. It was, however, "high-pressure" salesmanship and a little overpowering. For in the one half-hour we were brought through chelating compounds, stereochemistry, optical isomerism, and dextro and laevo optical rotation. This seems to be very fast, even for a refresher course. Just what the harassed early-morning housewife expects to get from this is a puzzle. Perhaps some like being impressed by learned sounds and pictures. The claim that 100,000 view this daily, even if true, means nothing, for it is certain that for the majority of these the result must be in the nature of a soporific rather than anything else. If, as is claimed, these refresher courses are helping teachers, then it is time more sensible hours were found for the broadcasts than the early morning.

Certainly scientific and educational television in the U.S.A., both on open and on closed circuits, is in a period of exciting development.

CHILDREN IN HOSPITAL

VILMA SCOTT

The importance of maternal care to the development of the total personality is well known. Recent evidence indicates that separating a child from his mother in critical circumstances such as illness may do him permanent harm.

One hundred years ago a newborn baby stood a one-in-five risk of dying before his first birthday. His life expectation at birth was thirty-six years. If he escaped scurvy or ricketts during childhood, he was faced with the epidemic diseases of smallpox, cholera, typhoid and typhus fevers, scarlet fever, and diphtheria. Babies born today run a risk of less than one in fifty of dying before the age of twelve months, and the life expectation at birth is sixty-six years. With a few exceptions the epidemic diseases are almost conquered. To take diphtheria alone, the incidence in England and Wales in 1948 was 3560 reported cases of whom 155 died. By 1958 there were thirty-eight cases reported of whom six died.

These advances are due as much to improvements in medical techniques as to the humane attitudes which have assisted their ready application. Although there have also been great achievements in the promotion of mental health, these—for obvious reasons—are more difficult to measure, and we are still far from the day when medicine and psychology work smoothly together to ensure the total health of the patient. To be sure, there are areas of co-operation, but on the whole the claims of psychologists are met with moral bias, indifference, or disbelief. Such was the reaction, by and large, to the proposals put forward ten years ago by James Robertson, a psychoanalyst member of the Tavistock Child Development Research Unit, regarding the hospitalisation of children under five years old.

The intense distress of young patients in hospital had often been observed by medical staff, and some considered it a normal, though superficial and temporary reaction which disappeared as soon as the child became settled. As to what caused the distress, not everyone was agreed. Some put it down to the illness itself, others to "spoiling" by the parents or to anxiety transmitted from the parents to the child, and still others to the strange and (to a child) frightening atmosphere of the hospital. On the basis of systematic studies* in hospitals in Britain and elsewhere, Robertson concluded that it was predominately a symptom of grief caused by the separation of the child from his mother. Because of the danger that the child may suffer permanent psychological harm, Robertson argues that the provision of maternal care to a sick child is as important as asepsis. Wherever possible, a child under five should be nursed at home or admitted to hospital with his mother. Failing this, a permanent mother-substitute should be assigned in hospital.

There have been no controlled studies to test this specific hypothesis, and this may be why there are still many who ignore its significance. Most of us have a feeling that over-protectiveness can harm a child's development as much as can callousness; and we all feel, to varying degrees, that a certain amount of rough-and-tumble, emotional and physical, is a good thing. We do not feel, however, that it is over-protecting a child to provide him with sufficient vitamins to ensure the development of a strong and healthy body. Those studies which have been done show that children suffer from being separated from their mothers, and that the damage may be permanent. Children in hospital without their mothers are under the additional stress of sickness and pain.

W.H.O. STUDY

In 1950 Dr John Bowlby, a consultant child psychiatrist and director of the Tavistock Child Development Research Unit, made a study of the effects of mother-child separation for the World Health Organisation.[1] The report included a review of the studies of young children in hospital. It was found that those who received extra mothering from the staff fared better than those who received no such tenderness and affection. Moreover, with some very young babies, there were reports of spectacular changes upon their being restored to their mothers. One such is the case of a four-month-old baby who, after two months in hospital, weighed less than at birth, and was in a critical condition.

> "His appearance was that of a pale, wrinkled old man. His breathing was so weak and superficial that it seemed as though he might stop breathing at any moment. When seen twenty-four hours after he had been at home he was cooing and smiling. Though no change had been made in his diet he started to gain promptly and by the end of the first year his weight was well within the normal range. He appeared to be in every way a normal child."

In the study of children from six to twelve months old, Dr Rene Spitz in the U.S.A. reported that prolonged separation led to mental illness. The children showed definite signs of depression: they were apprehensive and sad, withdrawn and unresponsive, and often sat inert and dazed. They had poor appetites and consequently lost weight; lack of sleep was common. Activities were retarded and there was a sharp drop in general development.

Later evidence has revealed that not all children suffer lasting damage, and some suffer less than others, but the case remains that the separation of a young child from his mother is not to be undertaken lightly.[2] By way of analogy,

* See Robertson, J., "Young Children in Hospital", Tavistock Publications, 1959.

not all children used to succumb to gastro-enteritis as a result of drinking unsterilised milk or milk from unclean containers. But the rate of severe illness and infant mortality from this cause was high enough to provoke an all-out campaign for meticulous care in the preparation of milk feeds for young babies.

In the report to the Central Health Services Council of the Ministry of Health[11] the Platt Committee recommends that the hospitalisation of children under five should be avoided whenever possible, and that "special attention" should be given to devising means to achieve this end. While recognising that medical training must concentrate on the physical aspects of illness, the Committee warns that the failure to take account of the child's emotional and mental needs "may cause lasting harm, undermining the child's self-confidence, his established habits, and his capacity to develop and mature".

The report mentions personality disturbances following hospital admissions, which are frequently reported by parents. Regression in toilet training and regression to infantile behaviour are common—even some four-year-olds want to be spoon-fed again, and to nurse from bottles. Disturbed sleep with nightmares, exceedingly difficult behaviour, aggressiveness (particularly towards the mother), and frequent temper tantrums are common.

James Robertson[7] cites the case of a two-year-old who spent eighteen months in hospital for pulmonary tuberculosis. When she returned home she was defiant, and for a year after discharge continued to be hyperactive, wilful, and given to temper tantrums if frustrated in the slightest. She was wantonly and aggressively destructive. She was unaffectionate, shrugged off the attempted caresses of her parents, and showed an excessive interest in sweets and other tangible signs of satisfaction.

During the first month of her hospital stay this little girl had been bitterly unhappy at being separated from her parents. She wept and threw herself about on her bed "like one demented", and when her parents came for their weekly visit she would cling so tightly to her father that she had to be removed by force. Towards the end of her stay she no longer spoke of her parents between visits, took little notice of them when they came to see her and, as her mother observed, seemed to be more interested in the gifts they brought her. On some occasions she seemed impatient for them to leave.

Many medical people dealing with children in hospital have come to feel that a certain amount of fuss during the first few days is to be expected; after this the child usually settles down and accepts the situation in which he finds himself. In their view, when a child ceases to be disturbed after visits by his parents it is a healthy sign that he is making a good adjustment. To Robertson's view this is a sign of danger. It does not indicate that the child no longer feels distress, but that he is no longer willing to show it. It is abnormal for a young child to be indifferent to his parents' coming and going.

If a child is happy and well-adjusted at home, and if he is truly contented while in hospital, it would be expected that the normal, affectionate relationship he enjoyed with his parents before admission would continue once he was home again. That personality disturbances so commonly follow hospital admissions and endure for a long time in some instances indicates that all is not as well as may seem. The regressive and difficult behaviour which follows short-stay admissions sometimes lasts for as long as a year. In cases of long-stay admissions begun before the age of four, disturbances have lasted for as long as eight years. These children tended to have difficulty in making and sustaining relationships; they were superficial, immature, excessively stubborn and self-centred, distractible, and unable to concentrate so that they made poor use of their mental abilities.

TWO FILMS

Physiologically, a child is mature enough to grasp the meaning of "now" when he is eighteen months old. By the time he is two years old he can understand "soon" and as he gets older he achieves enough control over his reactions to be able to wait for short periods. The three-year-old comprehends "not today", and although he uses the words "tomorrow" or "yesterday", he usually means merely "not today". A child may not be able to discriminate verbally between morning and afternoon until he is six years old.[5]

Children of four or under find separation from their parents difficult to comprehend, even under ordinary circumstances. They are still extremely dependent and in this age group it is normal for them to be selfish, demanding, and jealously possessive of their parents, particularly of their mothers, who are a fundamental part of their environment. If to the shock of separation are added illness, pain, fear, strange instruments and people, and an unfamiliar routine, a hospital admission becomes a traumatic experience with which the child is too immature to cope. No matter how carefully the need for hospitalisation may be explained, most children under five cannot understand why their parents should abandon them to assault and hurt, and often imagine it to be a punishment for some wrong. As the child is usually most dependent upon his mother, it is her absence he most resents; he feels that she has deserted him when he most needed her support. Thus the child feels angry and mistrustful of those he loves, and is thrown into a state of anxiety.

Because of the difficulty of bringing home, merely by argument, the intensity of the distress felt by children in hospital, Robertson, in 1952, made the film, "A Two-Year-Old Goes to Hospital"[8], which caused some astonishment to hospital authorities all over the world. It is not a sensational film, although it does show up the effect of some routine hospital practices on a frightened and confused child. A perfectly clean little girl is led away from her mother by a stranger who removes the child's clothes and submits her to a bath with firm efficiency. The nurse is not unkind, nor is she rough, but she is a stranger in uniform. The child panics quickly. Meanwhile the mother is left sitting idle in the waiting-room. The film also throws into relief the fact that visiting time is not long enough. The child is usually upset or withdrawn when her mother comes, and by the time she has been won over, it is nearly time to go.

"A Two-Year-Old Goes to Hospital" was shot on £40

worth of film-stock with a hand-held camera. Robertson specified that the child to be filmed should have an umbilical hernia because it is an illness in which the patient is otherwise healthy on admission and which requires an operation so slight that the patient is usually active and apparently free of physical discomfort within a few hours. Other than this he had no part in choosing the child whose name was picked at random from the hospital waiting-list. She was found to be a cheerful, friendly little girl with unusual control over her emotions. She was two-and-a-half years old, never previously separated from her mother, and so far an only child, but another was on the way. As she was on the waiting-list, Robertson was able to study her behaviour before admission. Also, the child became accustomed to him and his camera and behaved quite naturally in his presence. Her parents had tried to prepare her for the experience of going to hospital, but she was too young to realise what it would mean. She was in hospital for eight days.

The routine admission, investigations, and visits by the parents constitute part of the film; the remainder consists of sequences made over the same period each day and at regular intervals. No scenes were rehearsed, no parts enacted, and no special situations arranged other than a play session with one of the nurses to allow comparison with the child's behaviour when alone. Natural daylight was the only illumination, thus no special apparatus was required. The patient was not separated from the other children, so ward routine was little disturbed. For several weeks before making the film Robertson spent a great deal of time in the ward "practising" with an empty camera so that both would be familiar and inconspicuous to the staff when the time came for shooting.

The film has been effective in illustrating that the "settled" appearance of young patients can be deceptive. To busy hospital staff this quiet little girl hugging her teddy bear and looking out of the window may well have seemed "settled". She did not fret nor demand attention; she rarely cried. The camera shows us a face which is anxious and sometimes angry as the child, from her window, watches the bus stop where her mother usually descends.

A calm, self-possessed little girl is seen to become strained, anxious, withdrawn, and hostile to her mother. The patient develops a nervous tic, a habit of fidgeting with her fingers; she picks at her nose and at the skin around her fingernails; she bites her nails and tugs her hair. On one occasion she attacks a hospital doll with murderous violence. The film ends with her discharge from hospital, but a follow-up study revealed the usual pattern of difficult, regressive, and anxious behaviour. Six months after discharge, when the child seemed to be normal again, she accidentally saw a sequence from the film while it was being shown to her parents. She flushed and said angrily to her mother, "Where was you all that time, Mummy? Where was you?" She began to cry and turned to her father for comfort, away from her mother.

Clearly, it would be better for young children to be nursed at home. If this cannot be managed, the next best arrangement is for the mother to be admitted to hospital with the child. Robertson's second film, "Going to Hospital with Mother", shows such a scheme in operation. The patient and her mother are taken to a cubicle, 10 ft. × 9 ft., which used to accommodate one unaccompanied child. It contains a locker, a cot for the child, a bed for the mother, and a wash basin. The other mothers in the ward are calm, although some of their children are very seriously ill, and morale is high.

The patient is twenty months old, the younger of two girls and has been admitted for repair of a para-umbilical hernia. She is "lively, mischievous, impatient of interference, and never far from her mother's skirts"[5]. As she is settled into bed by her mother, she is completely at ease. The unaccompanied child is usually in tears by this time. Immediately after the operation the patient is out of sorts, but her good humour returns as her physical condition improves. By the fifth day she is as lively and mischievous as ever. There are no withdrawal symptoms and no fretfulness. On her return home she showed none of the disturbed behaviour commonly seen in unaccompanied children. She took up her old relations with her playmates and sister immediately, ate and slept well, and had no temper tantrums. In short, she behaved as though she had never been away.

FUNDAMENTAL PRINCIPLE

If the mother's presence is important to her child's health, then her admission with her child should be routine in all hospitals. Unfortunately, even in some hospitals which have a mothers-in arrangement, the mother's admission is not automatic. It is up to her to take the initiative if she happens to know that such a scheme exists. One can't imagine hospital authorities relying on the patients to see that standards of cleanliness and hygiene prevail.

Because there is no underlying principle to direct the care of young patients in hospital, conditions vary from one hospital to another. There has been a general tendency in recent years towards making hospitals more agreeable to children. The wards have been decorated in brighter colours; playrooms, toys, and teachers have been provided, and (in some hospitals) unrestricted visiting has been allowed. Hospitals which used to forbid the bringing of toys from home, in the interest of hygiene, now recognise that such ties with home satisfy an important emotional need for the child. In some the staff are asked never to pass through a ward without stopping to be friendly and affectionate to a child. Others have volunteers from the neighbourhood come and administer doses of T.L.C. (Tender Loving Care) as prescribed on the child's medical chart. But such provisions are inadequate and are based more on kindness and a desire to keep up with the times than on fundamental principles. As the Platt Committee points out, the child in hospital should be handled by as few people as possible, for children suffer from passing through too many hands.

Systematic studies have shown that although improvements in ward management go a long way to alleviate the distress of children over four, they do not help the child under four. Prugh *et al.*[6] report on 100 young patients admitted to an American hospital for an average stay of

eight days. From these a control group was selected to receive routine treatment. Their parents could visit once a week for two hours, and had little encouragement to participate in the care of the child. There was no organised programme involving problems of adjustment.

The fifty children in the experimental group were studied after the management of the ward had been reorganised. Daily visiting was allowed, and the parents encouraged to look after the children. A special play programme with a nursery school teacher was incorporated, and other changes made.

Of the control group (those who received routine treatment), 92% showed signs, ranging from moderate to severe, of difficulty in adjusting to hospitalisation. After discharge 92% showed "significant disturbances in behaviour not present prior to hospitalisation". Three months later 58% remained significantly disturbed; and 16% were still disturbed six months later. Of the children in the experimental group 68% were significantly disturbed in hospital, and the same percentage showed disturbances after discharge. Three months later 44% were found to be disturbed. The check-up at six months was not possible with this group.

The study shows that although improvements in ward management reduced the incidence of disturbances, it still remained high. It also revealed that the highest incidence of severe reaction occurred among those three years old or younger. Thus, the improved conditions benefited the older children, but the younger continued to show significant disturbance.

There is also the conclusion reached by the Department of Paediatrics and Anaesthesiology at Albany Medical College, Albany, N.Y., after a three-year study of 140 tonsillectomies:

> "For most children under four years it is our observation that no amount of love and understanding will make up for the absence of the mother. When doctors realise how inextricably mental welfare is bound up with physical welfare, provisions will be made for a parent to stay with the hospitalised child. If only in the interest of physical well-being, a consideration of the child's emotional needs must eventually take precedence over rules, schedules, and the polish on the floor."[4]

It emerged at a conference of the World Health Organisation that the problem discussed here is unknown in some eastern European countries because it is the custom for the entire family to accompany a sick child into hospital. In western Europe, parents who can afford it can take a private room and the mother may then be admitted with her child. It sometimes happens in such cases, however, that the mother is prevented from caring for her child, and thus half the benefit of her presence is lost.

OBJECTIONS TO THE SCHEME

There are many objections to the proposal that mothers be admitted to hospital with their children. Hospital staff who have observed the anxious and irrational behaviour of some mothers when visiting their children, fear that matters would become worse if they were admitted into hospital. It has also been objected that such a scheme would cost too much, that there is a danger of cross-infection, that the mothers would get in the way and upset hospital routine, that it would not be possible to accommodate them without building special wards or depriving a child of a bed, and that children are more difficult to control in the presence of their mothers—thus examinations would be made more difficult.

Over thirty years ago the late Sir James Spence instituted a mother-child hospital unit at the Babies' Hospital, Newcastle upon Tyne[10]. Other hospitals, Amersham General Hospital and the Victoria Hospital for Children in London among them, have adopted the scheme in recent years, and in none of these have such fears been realised. In some cases the incidence of cross-infection has dropped.

The Platt Committee has had the testimony of hospitals which have tried the system to the effect that the children show less emotional disturbance during admission and after discharge, and that the mothers are much more relaxed and less apprehensive than when they come for a limited visiting time. By feeding her child, comforting him, amusing him, seeing to his toilet needs, and putting him to bed at night, the mother frees the nurse for her medical duties and reinforces her own self-confidence. A few continue to be anxious and unreliable, but most are calm and cheerful in doing a job to which they are accustomed. The Committee also points out that what the mother learns about the handling of her sick child will be valuable if the child should fall ill again at home.

In addition to attending to their children's needs, many of the mothers perform odd jobs which need doing around the wards although they are not required to do so. At the Royal Aberdeen Hospital for Sick Children, which was built for the accommodation of mother and child, the mothers are responsible for cleaning and tidying their own rooms, making their beds and their children's, washing and drying the crockery used for their own meals, bathing and changing their babies, and administering medication such as eye- and nose-drops. Formulas are prepared by the nurses, but the mothers boil the teats, warm the feeds, feed the babies, and rinse the bottles.

It is not necessary, however, to build special hospitals or special wings. Other hospitals which admit mothers have found that simple adaptations of existing facilities were quite adequate. For example, the Amersham General Hospital have added a bed and an easy chair to existing cubicles. The Victoria Hospital for Children provide beds which can be folded and stored out of the way when not in use. In an American hospital where the children sleep four to six in a room, the mothers are provided with a collapsible cot which can be stored away in the daytime. The beds and the mothers' meals, then, constitute the only additional cost, and the safe-guarding of the children's mental health makes this well worth it.

Although it is generally true that children are better behaved in their mother's absence than in her presence, examinations and medication have not been made more difficult. As the Platt Committee points out, nursing has been made easier, for any potentially frightening experience

becomes less so if the mother is present. It is already general practice in the doctor's office, at hospitals, and in clinics, to have the mother hold the child on her lap while the doctor gives an injection or makes an examination. Sometimes the child will wriggle or make a mild protest, but he is generally submissive.

Another objection concerns women with other children to care for at home. Generally, women with other children decline the opportunity to accompany a younger child into hospital, particularly if the other children are under school age. It does happen, however, that because the mother has already experienced difficult behaviour from a sibling following hospitalisation, she is eager to accompany any younger children who may require it. A survey[3] conducted at the Royal Aberdeen Hospital for Sick Children in 1955 showed that approximately one-third (53 out of 155) of the mothers admitted had other children at home. At Amersham General Hospital during the six months from January 1 to June 30, 1957, half the mothers admitted had other children at home, and the majority of these had one or two others. Admission figures dropped sharply for those who had three or more others.

So far, the organisation of social services is inadequate to help families cope with domestic difficulties in such circumstances. As Robertson points out, women with several children would be freer to care for a hospitalised child, the one who needs her most, if these services were to be improved. The Platt Committee recommends the extension of nursing services by local authorities so that mothers will have assistance in caring for their children at home, under the direction of a doctor. This should be done when the nature of the illness and home conditions permit it, so that hospitalisation can be avoided altogether, and it should be done for all children under five regardless of whether there are siblings. St Mary's Hospital, Paddington, run an experimental scheme with a team of consultant registrars and nurses who visit sick children in their own homes, and the Birmingham Children's Hospital have collaborated with the City of Birmingham in a comparable scheme.

The Committee also suggests that children be admitted as day patients (kept in overnight and discharged the next day) for surgical procedures which will permit it, and receive follow-up treatment at home. Of course, the doctor must be satisfied that the treatment can be given in this way without danger to the child, that the home is suitable for the follow-up treatment, and that adequate medical and nursing supervision can be provided.

The proposals put forward by James Robertson, and later by the Platt Committee, call for profound changes in the attitudes and training of hospital staff. A few hospitals have adopted Robertson's proposals during the past five or six years. There are forty-four hospitals in England and Wales where 90% of the patients are children. To the best of our present knowledge only three or four of these have made the admission of mothers a matter of hospital policy. Although the practice is very slowly becoming an accepted policy, it is often done arbitrarily: nursing mothers are admitted, or the mothers of children who are dangerously ill or who are visibly upset by separation, or mothers who especially ask to be admitted with their children. There are still many people who are in a position to influence hospital admission procedure and who consider the evidence to be controversial or the claims to be exaggerated.

A controlled experiment would stop all controversy. The evidence which already exists indicates that the harm done may be permanent, and although it may be extremely difficult to measure more exactly the extent of harm due to this single cause, that is no reason for assuming the harm to be insignificant. In a discussion of the effects of mother-child separation Dr John Bowlby[2] compares the position of the psychologists to what might have been that of research workers with regard to poliomyelitis a generation ago: "Early workers, impressed by the severity of the aftermath in certain cases of the disease, may well have over-estimated the proportion of patients who suffered residual paralysis. The fact that we now know that it is only a small minority who are left afflicted has not altered our estimate of it as a serious illness, to be prevented at all costs." He goes on to point out that with poliomyelitis we have some idea of its incidence and reliable methods for estimating the degree of residual disability; in measuring the effects of mother-child separation we have neither. "Lacking a basis for calculation, therefore, we are in no position to take calculated risks."

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NEW SCIENTIFIC INSTRUMENTS

MINIATURE MICROSCOPY

VILMA SCOTT

No larger than a 35 mm. photographic camera, the Cooke-McArthur microscope provides an image identical in magnification and detail with that of the largest conventional instrument, and has a number of unique features which commend it for laboratory work and research.

The first radical departure since the days of Hooke from the design of the general purpose microscope is an instrument which can be carried in the pocket. The Cooke-McArthur microscope is scheduled for large-scale production by Cooke, Troughton, and Simms, and threatens to render obsolete the "old blunderbus" type of instrument. It can undertake any operation within the range of the largest bench microscope, gives an erect image, is always in focus, is rust- and shock-proof, and can be used for high-power microscopy while held in the hand.

This microscope carries any three standard Cooke objectives, including oil immersion, and either achromats or fluorites, and standard eyepieces. It has a conventional condenser and iris, owes its compactness to a prismatic system which provides the tube-length, and many of its advantages to its inverted stage. The instrument requires no lubrication, as it is made of anodised aluminium alloy, stainless steel, phosphor bronze, and beryllium copper. The entire microscope is a rigid rectangular block measuring 4 in. × 2½ in. × 2 in., and weighing only 18 oz. It incorporates a built-in electric lamp which operates from enclosed batteries or from the mains, and which can provide lighting sufficiently intense even for immersion dark ground illumination. There is a complete range of accessories for specialised work.

While essentially a laboratory microscope, it is ideal for travelling and field work, as it can be used without a bench even in the vibration of an aircraft, car, bus, or train, by day or by night. Oil immersion or dark ground illumination can be achieved without difficulty while the investigator is sitting in a swaying canoe, standing in a village surrounded by a crowd of children, stooping by a pool in the jungle, or sitting astride a windswept ridge above the snow line, with the same results as may be achieved in the best equipped laboratory.

This remarkable instrument was designed for research and general purposes by Dr John McArthur in 1932 when he was a medical student. He used it in his hospital work, for medical practise in this country and in Africa, and for the discovery of the carrier of malaria in Borneo (1941) when he was Director of Malaria Research for Borneo, Sarawak, and Brunei. He worked out the details for its further advances in a Japanese prison camp.

When it seemed impossible to persuade

Diagrammatical Section through the Cooke-McArthur microscope, the eyepiece on the left, and objective and condenser on the right.

The possibility of attaching the McArthur microscope to a standard television camera is demonstrated by the inventor, Dr John McArthur.

The McArthur microscope attached to a standard Paillard-Bolex H.16 16 mm. cine camera.

any firm of its value, Dr McArthur set up his own workshop. With this limited production it proved its worth and came into use in every continent. It is now used in many research laboratories, and supercedes the very large and costly instruments. It is currently in production in York, under the supervision of the designer.

Principle, Stage, and Focusing

Light enters the microscope from above, either from its stainless steel mirror (which also forms a dust cover for the condenser and iris) or directly from its built-in electric lamp. The lamp, operating on 1·5 volts is sufficient for ordinary or routine microscopy to the highest powers; when operating on 3 volts with two dry cells in series, it is sufficiently intense for high-power dark ground illumination, instantaneous photomicrography and projection, while long-life mercury batteries provide many hours of illumination.

The beam of light passes downwards through the iris and condenser to the specimen, and so through the upwardly directed objectives. The beam of light forming the image is reflected through a prismatic system, first horizontally along the base of the instrument, and finally upwards through the eyepiece. The prismatic system is solidly mounted in a removable sealed tube which can be interchanged with other light tubes for special purposes.

The inversion of the stage provides some of the microscope's unique features. When supplied with a simple light tube, the microscope gives an image which is erect, but reversed from left to right (that is, a mirror image). When an erecting light tube is supplied it gives a completely erect image, making operation more convenient, especially for dissection and other manipulations.

The slide faces downwards on the stage so that all normal specimens are held in the plane of the stage, and are unaffected by the thickness of the slide. Thus focusing is automatic, even with the highest powers. A small degree of fine adjustment is provided for the examination of different levels of specimen, but it is possible to examine a whole series of blood films, for example, with the oil immersion lens, with rarely so much as half a turn of the control to sharpen the detail. All normal specimens are in focus as soon as they are placed on the stage. It is impossible to crash the objective through the specimen. The inverted stage offers no difficulty with wet specimens, as might be supposed, but on the contrary has special advantages with these and with suspension and sediments.

The three standard objectives give magnifications from 30× to 1500×. The lenses are permanently mounted, parfocal, and centred in line on the objective plate. If more than three are used, these may be mounted, also parfocal and centred with the others, on a separate objective plate. It is a convenience for laboratory work to have, for example, a series of dry objectives such as 10×, 20× and 40× on one plate, immediately interchangeable and parfocal with a series of immersion objectives such as 50× fluorite, 100× fluorite, and stopped-down dark-ground objective on another, with possibly a series of phase contrast or metallurgical objectives on a third plate.

Since the objectives are virtually in permanent focus, the condenser can also be prefocused. There is a series of condensers including a two-lens Abbé, a dry achromat, an oil immersion achromat, and an immersion dark ground condenser, each of which can be precisely and permanently centred and prefocused so as to be in immediate adjustment as soon as it is dropped into place.

Accessories

A number of accessories can be incorporated. The standard monocular eyepiece tube can be removed and replaced with a binocular, or with a demonstration or comparison eyepiece. The instrument has a new form of gliding stage which allows fine control of the movement of the specimen. A perforated slide allows a lying drop preparation to be examined, with every advantage over the hanging drop preparation. Dissection, aided by the erect image, is provided for by long focus lenses and a supplementary stage, while micro-dissection can be performed even with the oil immersion objective. It is also possible to examine sediments in quite large volumes of fluid with the oil immersion lens, and several other unique operations can be performed under special circumstances.

The immersion dark ground condenser outfit provides a valuable source of illumination for small particles in suspension, rendering them visible when they are otherwise too small to be seen. Its particular application is for the examination of spirochaetes, especially in yaws surveys.

With the conventional microscope a dark ground condenser is difficult to adjust, requiring critical centring and focusing and an intense external source of light. Since the objectives of this microscope, however, are virtually in permanent adjustment, the dark ground condenser can also be permanently focused and centred for the individual microscope with which it will be used, and the built-in electric lamp is sufficiently intense to provide a beautiful dark ground illumination even with the highest powers.

The microscope can be combined with a photographic 35 mm. camera, making a small, rigid unit which can be carried in the hand or can rest conveniently on the bench. The camera forms a stand which raises the microscope to an appropriate height, and permits instantaneous photomicrography in monochrome or colour without interruption of the image.. The microscope may also be screwed to a television or cine camera exactly as though it were itself a lens. It may be swung into place already focused, allowing images of living organisms to be projected on to a screen.

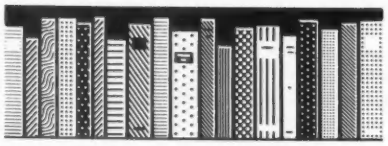
Other accessories include an expanding Perspex case, a leather case in two sizes, a supplementary electric lamp unit, and a transformer outfit.

Applications

While originally designed for medicine and medical research, the Cooke-McArthur microscope is now being introduced into industry, with particular advantages for metallurgical work. In addition to its usefulness in such operations as blood counts, measurement, and the examination of sediments in a fair volume of fluid, it facilitates the examinations of awkward surfaces such as those of aircraft, ships, and machinery.

It it an extremely rugged instrument, and has been thrown from the window of an aircraft at 500 ft., without a parachute and simply wrapped in plastic sponge. It landed without damage, still in focus, and ready for the examination of a blood film with oil immersion, immediately on unwrapping. It has been carried by breeches buoy to a lighthouse in the Atlantic, and run over by a motor car without damage. It can be sent conveniently by airmail.

As far as possible, the microscope has been made resistant to climatic conditions at the poles and in the tropics. The Fuchs Trans-Antarctic Expedition used it for medical work and for the examination of snow flakes. The microscope has identified malaria parasites during a flight over the South China Sea, and pathological specimens in flight over the Alps, and has been used for very high power photomicrography of blood parasites in the vibration of a crowded bus in Piccadilly. In addition to its adventurous career, the Cooke-McArthur microscope offers all the advantages for field research, and an image which satisfies the most critical standards.



THE BOOKSHELF

Francis Bacon: The First Statesman of Science

By J. G. Crowther (*London, The Cresset Press, 1960, xv+362 pp., 35s.*)

This book has two great merits: it is readable and it is opportune. The four-hundredth anniversary of the birth of Francis Bacon falls in 1961 and the tercentenary of the foundation of the Royal Society falls this year and was celebrated in London, in July. The youthful and formidable historian of the Society, Bishop Thomas Sprat, said in 1667 that some of Bacon's writings gave a much better idea of the aims of the Society than anything that he could compose.

Mr Crowther, having gazed steadily at the vast and irregular landscape of Bacon's life and work, makes a division into two parts "For Mankind" and "For Himself". The first has most of the sunshine in it. It reviews Bacon's transcendental aim for the departmentalising of "all knowledge" and more particularly that relating to the ultimate triumphant end, man's dominion over Nature. The extraordinary prescience of much of the plan, the convincing need for the new method of work, the desperate anxiety of the master-planner lest men should not bend all the weight of their effort to the crusade emerge very clearly from Mr Crowther's account. Perhaps not enough is made of Bacon's own subjugation to much of traditional scholarship. At any rate, the sense of urgency, the selflessness of the pleader and the skill of the propaganda are shown in their right relation to Bacon's zeal as a planner. It is curious to reflect that only now has England achieved a Minister for Science when so much of the Great Design has, so to speak, "happened" and without the aid of a master-plan.

The second part of the book deals with the life and is a fair account in which due tribute is paid to that greatest of editors, James Spedding. Mr Crowther brings a calm acceptance of fact which is better than a forced sympathy to his subject but the great Verulam eludes the biographer as in life his likeness eluded the portrait painter. The division into two distinct halves brings a clarity to the reader's own appraisal of this extraordinary man. The immense intellect, working alone, always struggling to an ideal plan, at one moment speaking in brilliant parables and the next achieving the clarity of an experiment or an axiom or a true division of labour is well appreciated. The life spent in pursuit of who knows what magnificent dream gives in the end the impression of a soaring intelligence, hampered by lack of self-knowledge as the man himself was chained by insufficient means, by ill health and most of all, by lack of charm. The advantage of Mr Crowther's book is that it makes the reader ready to read some Bacon; it reminds one of the great bell-ringer, so much in need of honour and in so much deserving it.

"If a man perform that which hath not been attempted before . . . he shall purchase more Honour than by Effecting a Matter of greater difficulty or Virtue, wherein he is but a Follower." M. LINSTEAD

Year Book of The Royal Society 1960

(*London, The Royal Society, 1960, 302 pp., 21s.*).

The Royal Society's "Year Book", issued early each year, is a reference work for those associated with scientific affairs and for all libraries interested in scientific developments. It contains a list of Fellows and Foreign Members with their current appointments and addresses corrected to January 1 of the year of publication. The membership of Royal Society committees and committees formed jointly with other bodies are also included. For example, the "Year Book" contains the membership of the National Committee for Space Research, formed by the Royal Society to co-ordinate United Kingdom activities in space research and to advise on the scientific aspects of the British programme. The Society is the adhering organisation for the United Kingdom to the International Council of Scientific Unions and has appointed national committees in the various branches of the natural sciences.

The Royal Society Research Appointments are listed and scientific reports of the work undertaken by professors, fellows, and students are printed. The regulations governing these appointments are also given. To complete the volume the Statutes, the Annual Report of Council, Medal Awards and Lectures, Funds, and a summary of the accounts are included.

Heavenly Clockwork

By Joseph Needham, F.R.S., Wang Ling, PH.D., and Derek J. de Solla Price, PH.D. (*Cambridge University Press, 1960, 229 pp., Illustrated, 65s.*).

Until recently, it has been generally believed that the mechanical time-keeper was invented in Europe about the beginning of the 14th century.

In 1956, however, the authors of this book disclosed in a letter to *Nature* that this belief was incorrect and that the credit of making a much earlier mechanical clock must go to Su Song in China in A.D. 1090.

Now Drs Needham, Wang Ling, and Price have published this full-length book setting out in detail all that is known about Su Song and his extraordinary mechanism. This important book, therefore, should be read by all interested in the history of technology in general and the history of horology in particular. It certainly gives one furiously to think that in the same era as the Battle of Hastings, a Chinese savant was constructing an astronomical clock and tower (probably 30–40 ft. high) with mechanically driven armillary sphere, celestial globe and a series of jacks, bells and drums to strike the hours.

The authors then show that the design of Su Song's clock may be traced even farther back to a mechanical clock made in A.D. 976, and that this can be traced even farther back still to a mechanical clock made by I-Hsing in A.D. 726.

The most important point is that these early clocks were weight driven, but the weight was that of a given volume of water (or mecury), and that the motion of the gear train was regularised and kept in check by means of an escapement.

Su Song's clock must have been an amazing piece of mechanism when we consider that the gear wheel was 11 ft. in diameter, several of the wheels had 600 teeth and that a chain drive of about 20 ft. long was also used. The main, vertical, time-keeping shaft together with its jack wheels is estimated to have weighed half a ton.

In view of the size of some of the components and of the fact that many of them were cast in bronze, it is a great pity that nothing still remains (or has been recognised) of these extraordinary mechanisms.

On reading this book one cannot help asking the question why such machines were invented at all, either in Europe or in China, and one can hardly avoid coming to different conclusions for each

locality. While the authors incline to the view that all early civilisations were interested in making mechanical models of the universe, the Chinese were particularly interested in calendrical problems since it was the royal prerogative of each Emperor to make a new calendar.

Su Song's clock was essentially a calendrical mechanism, and the fact that it told the time by means of bells and drums appears to have been of secondary importance. In Europe, on the other hand, circumstances were different, and new calendars were not required with comparative frequency. It was, however, important to know the time for religious purposes. The majority of early European clocks remaining (or reliable descriptions of them) make it clear, almost beyond doubt, that religious needs were the necessity which mothered the invention. Their first, and most important, job was to ring a bell at fixed hours. The visual telling of the time by means of a dial came later. Early clocks with calendrical functions are most unusual and are the exception.

The authors are very accurate in most of their statements concerning early technology, but their date (1832) for the use of chain drive in Europe is somewhat in error. The Conservatoire des Arts et Métiers possesses a machine made by the celebrated Vaucanson (*c.* 1745) for forming the links of a chain for drive purposes. Similarly, the date given for blast furnaces for producing iron in China as a century before the beginning of our era, seems to have overlooked the Hittites who were making iron in blast furnaces in about B.C. 1400.

This book constitutes a milestone in our knowledge of early science technology and horology; and, as such, should be read by all interested in these subjects.

It is perhaps the most important book on these matters to be published in this century.

R. MC. V. WESTON

Industrial Research and Development Expenditure 1958

(*London, H.M.S.O., 1960, iv+13 pp., 1s. 3d.*)

This report of the DSIR published on April 13, 1960 under the imprimatur of the Economic Committee of the Council for Scientific and Industrial Research is the second of a series: the first was "Estimates of Resources Devoted to Scientific and Engineering Research and Development in British Manufacturing Industry 1955" (see DISCOVERY, 1959, vol. 20, No. 3, p. 136).

The method used in carrying out this recent inquiry was similar to that used in the earlier "pioneering" venture. The basic data was collected by the DSIR who sent out a questionnaire to certain companies on expenditure on research and development, from which estimates of outlay per fully qualified research-worker were constructed; and also by the Ministry of Labour, who carried out a fairly comprehensive sample-survey of the manpower employed on research and development. From these two studies, supplemented by a parallel survey by the Iron and Steel Federation, and by data from the Ministry of Aviation, overall estimates of national expenditure on research and development were constructed. These are believed to be tolerably accurate, certainly more so than the earlier inquiry.

While the results of the two inquiries are not exactly comparable, it is clear that there has been a major increase in the expenditure on research and development by manufacturing industry from about £190 million to £300 million. Even allowing for inflation, it has risen from 3·1% of manufacturing industry's net output to

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4·2%. The welcome fact, however, that research and development expenditure increased markedly in a period of relatively static national output should make us cautious about linking too closely scientific effort and national production: general economic policies must not be overlooked.

Perhaps equally significant over that period was the relatively declining role of defence-research, from nearly two-thirds of manufacturing industry's expenditure in 1955 to under a half in 1958. In other words, "civil" research and development has approximately doubled. Of special significance is the rising outlay per qualified research-worker. Outside aircraft, and allowing for rising prices, expenditure has risen by over a quarter: this is mainly attributable to a 50% growth in the ratio of supporting staff per qualified worker. Capital expenditure is a surprisingly minor item in the research bill—about 10% in all.

Despite the decline in the significance of defence, three industries—aircraft, electrical engineering and chemicals—still account for the major part, in 1958 over two-thirds, of manufacturing industry's outlay. Whereas this Report is less detailed than its predecessor on outlay and employment by specific industries, useful information is thrown up on the significance of research by outside bodies for industry—co-operative research associations, Government research laboratories, etc. The fact that the proportion of this type of outlay is highest for industries comprising a large number of small manufacturers is of the greatest importance; it spotlights the need for the most careful examination of the research arrangements of Britain's more traditionally based industries.

A History of Metals

By Leslie Aitchison (*London, Macdonald & Evans, 1960, 2 vols, 647 pp., £8 8s.*)

This book will appeal to those who have forgotten most of what they learnt about metals at school, as well as to those who are working in the industry. This vast subject has been reviewed by Dr Aitchison with great skill, and despite the wealth of detail, his treatment is never dull, nor so technical as to be beyond the layman's understanding.

Up to the middle of the 19th century, the author has been able to maintain a proper balance in dealing with so broad a canvas covering many scientific disciplines, as well as political and economic history. But such key developments as the Bessemer converter, the Siemens open-hearth furnace and the Gilchrist-Thomas process, surely merit more generous treatment than has been accorded to them on pages 512 to 518. The history is up to date and includes the transuranic metals, but it is a pity that there is no mention of such recent technical advances as the use of oxygen in steel making and the special rolling techniques employed in producing steels for the electrical industry. The account of the non-ferrous metals, though brief, is adequate, but it would have been usful to refer to the Bayer process for preparing alumina from bauxite.

Only top people can afford to own this book, but one hopes that its price will not deter public and works libraries from buying it—there are many who will wish to borrow it. The abundant illustrations are admirable, and the publisher and the printer deserve unstinted praise for the careful proof reading and the admirable presentation of these two volumes. L. F. HABER

The Transactions of the Newcomen Society

Vol. XXX, 1955–6 and 1956–7 (*281 pp. and 62 plates*)

The aim of the Newcomen Society is to encourage the study of the history of engineering and technology. Its statement of objects says that "whatever doubts may exist as to the reality of the progress made by the human race in other directions, no one will question the advance that has been made in material well-being . . . an advance achieved through the labours of a long succession of engineers, inventors and manufacturers." One would not get this diffident tone from our Victorian forefathers, who never doubted the reality of progress, perhaps because they had seen such outstanding changes in material comfort. The Society thinks, probably rightly, that a truer appreciation of past achievements may make us "see events in truer perspective and make a wiser estimate of what should be the direction of future events." In England, engineers seem to be interested in the history of their calling only in one or two fields—old steam-engines, old railways, old canals. the Society has only 500 members, but an off-shoot society in America has 14,000. A little publicity in the right places could surely increase the home numbers. In the present volume there are papers on early locomotives, water-mills, and windmills, the Little Ouse River Navigation and the construction of early cotton-mills—something for all the devotees in separate sections. This handsome volume with its large number of plates is free to members for the annual subscription, it is well worth any engineer's money and many school libraries would find it eagerly read.

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GEOPHYSICS AND SPACE RESEARCH

By ANGELA CROOME

Final Plan for Indian Ocean

The final arrangements for the 13-nation, 12½-million-dollar Indian Ocean expedition were expected to be completed at two meetings in Copenhagen last month (July). The SCAR steering committee for this expedition was holding its final meeting before the first ships to start measurements sail, and UNESCO, which is taking an increasingly large interest in the study of the seas, was to consider its participation in work on the Indian Ocean. The period of the Expedition runs from the end of this year to the end of 1964, with peak activity during 1962–3. At least 15 "ship-years" are likely to be spent on the study.

Although the Indian Ocean covers 14% of the Earth's surface (a greater area than Asia and Africa together) knowledge of what lies beneath the surface of this ocean is no more advanced than mapping of the Earth's land areas was 250 years ago—that is, before Australasia and the Antarctic had been discovered.

The Indian Ocean has several unique features. Nowhere else in the world is there a similar seasonal reversal of the prevailing wind. The wind system in that part of the ocean lying above the equator is characterised by the two monsoons, one blowing from the north-east for approximately six months and the other blowing from the south-west for the rest of the year. This phenomenon has a vast but essentially still unknown effect upon the currents and organisms in the waters.

Another notable feature is the apparent productivity of the ocean. In June 1957 a Russian ship, not far from the main trade route between Colombo and the Gulf of Aden, reported millions of tons of dead fish floating in an area some one thousand kilometres long and two hundred kilometres wide extending across the middle of the ocean. Similar reports came simultaneously from British ships in the region. During the same year smaller fish kills were reported in nearby parts of the Arabian Sea. It is not known how the fish were killed, but the very size of this catastrophe gives some idea of the potential mid-ocean resources which are currently untapped. There is further fragmentary evidence of unusually high productivity.

A quarter of the world's total population lives in the lands that border this ocean's shores. These happen to include the peoples living nearer the starvation line than any others. There seems much promise that the Indian Ocean might be capable of supplying the much-needed protein food sources to help feed this hungry and rapidly increasing population.

No Gas In Space?

The analysis of data on the volume of ionised gas in regions close to the Earth and in interplanetary space has now been completed by Russian scientists. The material was obtained through the use of ion traps in the three Soviet *Luniks* launched between the end of 1958 and the end of 1959. The conclusions are both interesting and unexpected, and are based on a total of 12,000 individual readings. The distinguished Soviet astrophysicist I. Shklovsky has been in charge of the data interpretation.

There are two main conclusions:

1. There is a considerable concentration of ionised gas, assumed to be predominantly hydrogen, surrounding the Earth to a distance of about 14,000 miles. This halo of highly rarefied outer atmosphere or "geo-corona" is thought by Shklovsky and his colleagues to be supplied by the evaporation from the oceans of water upon which the Sun's radiation then acts to produce ionisation. The number of particles in this region (lying roughly above 1000 miles and below 14,000 miles up) is of the order of some hundreds of positively charged ions/c.c.

2. In contrast, the measurable concentration of ionised gas in interplanetary space (that is, beyond 14,000 miles from the Earth) is negligible. The instrumental limitation of the experiments puts the ion density at less than a few dozen particles/c.c. Indirect evidence—that derived from analysing the currents in the traps—suggests that the concentration may be lower than this. This is what may be called the "stationary" gas in space. During periods of intense solar activity jets of ionised gas sweep across space from the Sun temporarily elevating the gas-density along their path.

Dr Shklovsky gives the following account of his view of the geo-corona: "The lower layers of the Earth's atmosphere always contain water vapour. Higher, above 65 miles from the Earth's surface, the Sun's ultra-violet radiation breaks up the molecules of the water into their component atoms of hydrogen and oxygen. Up to 100 miles out, the Earth's atmosphere is well mixed, and for that reason the relative proportions of hydrogen atoms is more or less constant. But still higher up, the atmosphere ceases to mix and the higher up we go the more there are of the lighter hydrogen atoms.

"At a height of between 1000 and 1250 miles, hydrogen becomes the main element in the Earth's atmosphere. The speeds hydrogen atoms attain in their thermal motions are fairly large, above the primary cosmic velocity in most cases. Consequently, the hydrogen atoms in the outermost layers of the atmosphere keep escaping—seeming to vanish into interplanetary space. It is these hydrogen atoms that form the 'geo-corona'.

"If there were no steady replenishment due to evaporation of ocean water, all the hydrogen in the Earth's atmosphere would vanish into interplanetary space somewhat speedily. Calculations have shown that this is why the level of the world ocean has dropped by several metres in the course of the Earth's geological history."

The X-ray picture of the Sun

The first x-ray photograph of the Sun ever obtained was made by U.S. Naval Research Laboratory scientists using a specially designed "pinhole" camera flown above the atmosphere in an *Aerobee-Hi* rocket at the end of April. This photograph is a direct enlargement from the original film. It shows the Sun as seen from 130 miles above the Earth's surface in x-ray light. The outer ring round the periphery of the disc is brightest since the camera is looking edgewise through the densest concentration of x-rays, that is, edgewise through the inner corona from which the x-rays are principally emitted. Because the shell of gas

X-ray photograph of the sun made by Richard L. Blake, U.S. Naval Research Laboratory. Photograph was obtained from an *Aerobee-Hi* rocket launched from the Naval Missile Test Facility at White Sands Missile Range, April, 1960.

which constitutes the inner corona is completely transparent to the x-ray emission it looks dimmest in the centre of the solar disc where the emitting region in the line of sight is thinnest. Virtually all of the x-ray emission was found to be confined to a height of one-fifth of a solar radius above the disc.

At the time of the flight, in addition, a bright visible plage of calcium light was present just above the solar equator. This region also appeared to be responsible for a brilliant x-ray emission—as may be seen from the bright patch on the x-ray photograph.

The most important emission lines in the non-visible light spectrum of solar ionising radiations occur at the resonance frequences of hydrogen (Lyman-α, 1216 Å), and of singly ionised helium (304 Å). These two emissions far outshine all of the ultra-violet radiations of all the other elements in the solar atmosphere. At still shorter wavelengths, the Sun emits x-rays whose total intensity is highly variable over the eleven-year solar sunspot cycle. The x-rays originate in the solar corona, where the temperature is of the order of 1,000,000°C. The x-ray flux reached a minimum in 1954 (at the trough in the solar cycle) and climbed to about five times the minimum value at the recent peak in the solar cycle, 1958–9. This photograph was taken close to the peak intensity period.

At its maximum the x-ray intensity amounted to about one-tenth the ultra-violet intensity in the hydrogen and helium emissions. These three major sources of ionising solar radiation account almost entirely for the normal production of the Earth's ionosphere. Reading from the lower level upwards: about 50 miles up, Lyman-α produces the D-region; x-rays produce the E-region from 60 to 90 miles up; helium 304 Å radiation produces the F-region above 100 miles high.

When the Sun is active, the most marked variations occur in the x-ray emissions. At times of solar flares, not only is the entire x-ray spectrum enhanced as the temperature of regions in the corona rises to more than 10,000,000°C, but very energetic x-rays are generated. The mechanism that produces the flare radiation is intimately related to the magnetic fields in the neighbourhood of sunspots. Observations of these fields by means of a magnetograph show that after a flare a large portion of the energy in the magnetic field has been dissipated, sufficient to account for the total energy release in the flare radiations.

As x-rays do not penetrate closer than 60 miles to the Earth, the camera for this experiment was made to operate when the rocket had reached 130 miles high; then the apparatus was separated from the rocket and parachuted to Earth. As x-rays cannot be focused by lenses or mirrors as with visible or ultra-violet light, a pinhole camera was used. The pinhole of the NRL camera that took this photograph was five-thousandths of an inch in diameter and covered by a thin plastic film painted with an opaque coating of aluminium. Visible light was thus blocked out while the x-rays were not. Wavelengths between 20 Å and 60 Å only were able to pass. Some smearing of the image took place due to slow rotation of the camera on its axis during the flight.

SPACE CALENDAR

END OF MAY

German Rocket and Space Society hold their annual meeting at Heidelberg. Three hundred attendance, including IAF President, Soviet Academician Leonid Sedov.

JUNE

1 NASA announces that the Rocketdyne division of North American Aviation Inc. will gain the contract for developing the 200,000-pound-thrust rocket engine for the upper stages of the giant *Saturn* space mission vehicle. Rocketdyne had four competitors for this contract. The engine may be used in clusters of two or four for the advanced *Saturn* configurations; it will be adaptable to on-off-on operation, have liquid hydrogen fuel, take about three years to develop and this will cost $44 million. The two-engine cluster upper-stage *Saturn* will boost 37,500 lb. into a 300-mile-high orbit; the four-engine cluster could raise 50,000 lb. into this orbit.

2 Further world-wide magnetic disturbances disrupt long-distance telecommunications as a result of early-April's solar flare region coming round to face the Earth again.

3 R. N. Bracewell, distinguished radio physicist at Stanford University, California, suggests in *Nature* article that technologically advanced communities in other universes might not merely beam radio signals for interception by Earth (see Project Ozma these Notes earlier this year) but might well dispatch automatic space-probes with pre-set radio programmes to communicate on our convenient frequencies from orbits in our close vicinity.

6 The visit of Mr Harold Watkinson (British Defence Minister) to Washington to obtain a suitable medium-range air-to-ground missile for use in British V-bombers culminates in an agreement between two Governments for Britain to have the *Skybolt* missile, possibly by 1964, and for British teams to co-operate with the Americans in developing this as-yet undeveloped vehicle. Cost to us understood to be extremely low and undertakings made that there would be "no strings attached".

6 3000 men working at *Atlas* missile centres go on strike for higher wages. One firing scheduled for this week postponed, but U.S. Air Force spokesman declares that

stoppage does not affect the "retaliatory" capability of the three *Atlases* at "ready" at the only strike base for these missiles, Vandenberg Air Force range, California.

6 Fourth launching in the series of huge *Skyhook* balloons designed to carry 8-foot-high emulsion stacks to beyond 20 miles high to record primary cosmic rays, took place successfully from Glynco Naval Air Station, Brunswick, Georgia. Fully inflated, the balloon was as tall as a fifty-storey building; and the total weight lifted, 2½ tons. Previous launchings, only one flight of which was satisfactory, took place from shipboard in the Caribbean in January. (See these Notes, August, 1959.)

7 *Blue Streak* launching-pad completed at the Woomera rocket range, Australia. It was so nearly finished at the time of the cancellation of *Blue Streak* for the defence programme that it was decided to go on. Mr Hulme, Australian Minister of Defence, announced at the same time that a team of British scientists and Government officials were to visit Australia to discuss the future of Woomera and the possibility of using *Blue Streak* for space research. No date fixed.

8 West German Defence Minister, Herr Strauss, leaves for U.S. to discuss the American offer to supply the Bundeswehr with the *Polaris* medium-range missile (assumed range 1500 miles) as an army weapon for launching from mobile land ramps. The Bundeswehr already has, or on order, the following missiles for its armoury: *Honest John*, 15-mile-range free-flying rocket; *Sergeant*, 60-mile-range ground-to-ground solid-fuel rocket; *Matador*, subsonic 625-mile range ground-to-ground; *Mace*, similar with 920-mile range. This gives it one of the most up-to-date weapons systems of any modern army.

9 X-15, U.S. experimental hypersonic rocket aircraft exploded on the ground during engine run up at Edwards Air Base, California. Scott Crossfield, its principal test-pilot was at the controls, but escaped unhurt, after being blown 20 feet in the forward section which tore off. The explosion took place in the 57,000-lb. rocket engine. The machine had not yet attempted its full mission to reach nearly 1000 miles high and 4000 m.p.h. under its own power, and then coast back to Earth under minimum control.

10 HMS *Devonshire*, the Royal Navy's first guided-missile ship, a destroyer, launched at Birkenhead. It carries one *Seaslug* and one *Seacat* (close-range) installation.

12 U.S. Defence Dept. announced that next spring experimental explosions of 500 lb. of dynamite will be made from balloons 24 miles above southern New Mexico. *Project Banshee* will yield data on the "effects of chemical explosions above the atmosphere" and "may also contribute knowledge to cope with military problems in the space and missile age".

14 Mr John Brickley of Pye Telecommunications Ltd revealed that a design already prepared by Pye engineers required only one valve powered by solar cells aboard a satellite in orbit to act as a multi-channel telecommunications relay from one side of the world to the other. The package "could easily be launched by the *Blue Streak*". Mr Brinkley was addressing the Commonwealth Press Union in London.

15 The three principal orbiting objects that resulted from the separation on May 20 of the pressurised capsule of *Sputnik IV* (the Soviet test "spaceship" launched May 15) had decreased in period in the following way by 6 p.m. Moscow time on this date: "spaceship", 94·16 min. (May 15, 91 min.; May 20, 99·56 min.); capsule, 94·16 min. (on separation, May 20, 99·56 min., with transit 16 min. behind "spaceship"); carrier rocket, 90·65 min. (May 15 and May 20, 91·2 min.). The May 20 periods for "spaceship" and capsule represent corrected versions of the new orbit then inadvertently acquired when the retro-rocket misfunctioned to put these two objects into a higher instead of a lower orbit.

21 Seventh successful *Black Knight* rocket test out of seven, at Woomera. This, the second successive test using a second stage to boost velocity of nose-cone at re-entry. Altitude achieved by first stage, 300 miles.

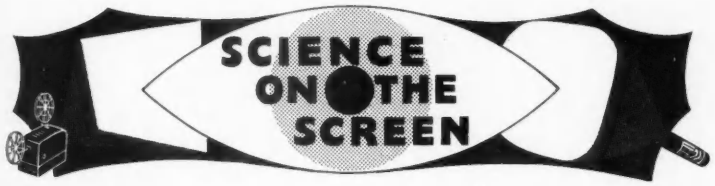
22 U.S. successfully launched two satellites (total weight 265 lb.) with one *Thor-Able-Star* rocket vehicle into similar orbits varying between 460 and 563 miles high, from Cape Canaveral. Orbital inclination, 65°, 'not exactly what was intended". Main satellite of 223 lb. and 36 in. diameter, is a *Transit 2A*, a more sophisticated version of April's *Transit 1B*, and part of U.S. Navy's series of navigational satellites due to be fully operational by 1962, and expected to be of use for weapons systems, including *Skybolt* and submarines. *Transit 2A* carries a high-precision electronic digital clock and uses power derived exclusively from solar cells. The 42-lb., 20-in.-diameter second satellite is the first Canadian orbiter, instrumented to observe "galactic noise", the long radio waves that cannot penetrate the ionosphere. This is one of the experiments scheduled for the four-experiment Canadian *Scout* satellite due next year (see April DISCOVERY).

22 The Jodrell Bank radio telescope made successful two-way contact with *Pioneer V* across 20 million miles of space. This distance is forty times greater than the previous long-distance record for tracking a man-made radio in space. Reception was of the small 5-Watt transmitter as the *Pioneer*'s batteries have not been able to sustain the power needed for the 150-Watt transmitter intended for longer-range communication. This enhances the achievement to the extent that Jodrell Bank scientists now believe that had the power supply been sufficient to operate the high-power transmitter, the probe could have been successfully tracked to 100 million miles. The signal became too weak to permit further tracking some days later.

28 Soviet Union announced tests of new multi-stage space mission rockets between July 5 and 31 and warn shipping and aircraft to keep clear of a comparatively narrow area in the Central Pacific in the vicinity of the Gilbert and Ellice Islands, where the penultimate rocket stage would fall. The rockets would be fired without the final stage.

29 The U.S. announced that there would soon be tests over the Pacific of the anti-missile missile *Nike-Zeus* using *Atlas* ICBM missiles as the target.

29 *Discoverer XII* satellite successfully launched from Vandenberg. This completes the originally scheduled series. None has been intercepted from orbit, the experiment planned.



Science Television

There is an old story illustrating the folly of the academic writer, which concerns a book devoted to the geography of Patagonia. According to the tale, this book had a chapter entitled "Snakes in Patagonia" and there followed the chapter, consisting of but one sentence, which read, "There are no snakes in Patagonia." In like manner it is an easy matter to write a review headed "Science Broadcasts on ITV", for the review then consists of the one sentence "There are no science broadcasts on ITV." It must indeed be lamented that science broadcasting on ITV is virtually moribund. Even the one little oasis in the desert, the Sunday series "It Can Happen Tomorrow", has been dropped for an alternative. There seems little hope for the emergence of a more reasonable approach in the near future from ITV.

The BBC on the other hand have very vigorously exploited the fact that July this year sees the celebrations of the tercentenary of the foundation of the Royal Society. Yet even here the way in which this important historical event has been exploited certainly reveals the curiously *ad hoc* manner in which science TV broadcasts are treated by the BBC, a manner which certainly appears to point to some inadequacy in the direction at the top.

We are aware of the fact that after the official opening of the Royal Society celebrations by Her Majesty there is to be broadcast an important historical programme which has been well thought out and to which notable contributors will be brought. (Unfortunately the inevitable delays in printing and publication are such that this article, written in June, will only appear some time after the July celebrations.) Indeed we look forward to seeing this projected historical programme and hope to report on it in due course. Yet in spite of this promise, inevitable criticism must be levelled at the BBC for its peculiar lack of balance in its presentation of the Tercentenary programmes.

It is a fact that for some months past already, once a week, we have had a sequence of Tercentenary science programmes linked with Fellows of the Royal Society. Practically all have been admirable, bringing to us fascinating and delightful *current* researches. Yet virtually no emphasis has been placed on the fact that a tercentenary is first and foremost a *historical* occasion. That what the Royal Society is celebrating this year is not its present status but its original foundation exactly three hundred years ago. This being so we certainly ought to have had more historical resumés of the formidable contributions of the Fellows of the Royal Society since 1660. Here was a golden opportunity for the BBC, but to a large extent it has been missed, for one historical programme, no matter how exciting it promises to be, can hardly be expected to compensate for this.

These past three hundred years contain the whole cream of the creation of our contemporary science, which is, of course, the very heart-beat of modern Western civilisation. At the central core of the evolution is the dazzling continuous record of the Fellows of the Royal Society, right through the whole of the three hundred years. They play key parts in the development of every branch of European science, whether it be astronomy, mathematics, physics, chemistry, biology, geology, or medicine. Indeed inextricably woven are the contributions of the Fellows with the development of the whole structure of science. This being the case surely it would have been more than appropriate to have impressed upon the vast lay viewing audience the real important historical links tied to the Royal Society. Why in physics alone, to select but one example, we range from Boyle and Newton some three hundred years ago to Rutherford and Einstein today (for he too was a Fellow, albeit a foreign fellow).

Not only scientifically but sociologically the Fellows have played their part. Of course we all know of Christopher Wren, the architect of St. Paul's, but how many know that he was a Fellow of the Royal Society? And even amongst professional scientists, how many know that at the same time it was to the distinguished physicist Dr Robert Hooke, Fellow of the Royal Society, that the job was given of rebuilding the streets of London after the Great Fire? Incidentally his admirable designs were wrecked by conservative traders who wished to see their old premises re-established. How many too know that the distinguished Fellow, Michael Faraday, was consulted by the government of his day with regard to sewage and manure problems of considerable economic importance? The point need hardly be stressed, for it is clear that there is more than ample material to fill several programmes. There certainly should have been at least four historical programmes; certainly at least one each in astronomy, the physical sciences, biology and medicine. As it is one does get the marked impression that the Tercentenary has proved largely to be a convenient peg on to which has been hung a group of programmes, each admirable by itself but planned with little reference to history. One fails to notice any master plan co-ordinating that essentially important aspect of a tercentenary, namely, its historical significance.

Having unburdened ourselves of criticism we are left with nothing but praise for the actual individual programmes tied to the Tercentenary. First "Eye on Research" brought us a succession of delightful programmes illustrating current researches of some individual Fellows, then an equally brilliant series entitled "Life Before Birth" was skilfully produced by James McCloy and admirably introduced by David Lutyens. These latter programmes were models of authoritative science broadcasting. They dealt essentially with the current state of knowledge about the oganisation of cells from the egg to the human adult. Yet fascinating as these programmes were, your reviewer still regrets the effective lack of emphasis on history which a Tercentenary celebration automatically conjures up.

S. TOLANSKY

ICI Films 1960

The ICI Film Library has issued a very well produced and illustrated catalogue. It contains 14 films on agricultural and veterinary subjects, 10 films on industrial medicine, first-aid, and safety, 19 science films for schools, 17 films about ICI, 7 specialised films, and a series of "panorama" films, and films about ICI products. (*All these films are available free of charge from ICI Film Library Imperial Chemical House, Millbank, London, S.W.1.*)

On the back page of the catalogue full details of how to borrow ICI films are given. The catalogue, which is free, can be obtained from the same address.

The catalogue gives a fairly full synopsis of all the films. As in most catalogues, the titles are often misleading and the synopsis has to be read in order to find out what the films are about. For example,

A Ship Comes In From Texas is actually about how sulphuric acid is made and used. L. GOULD-MARKS

Out of the Forest

35 and 16 mm. Eastmancolor. Sound. Running time 30 minutes. Produced for the United Steel Co. Ltd, by Wallace Productions Ltd, written and directed by Stephen Clarkson.

This film sets out to show how coal, which came from the prehistoric forests, is turned into coke and chemicals by the United Coke and Chemical Co. Ltd. It was made mainly at United Coke and Chemicals Sheffield Works. The gas from the coke-making process is fed by pipelines to other works in the United Steel Group.

The conversion also produces a range of valuable chemical derivatives. This is the object of the film: how far it succeeds, and how far it fails, is an interesting object lesson to all sponsors, film makers, and film users.

First, the photography is always clear and the colour good. The fault lies, and fault there is, in the gimmick on which the treatment is based.

The camera takes the audience along a corridor, through a door into the office of a white-coated chemist, who is to be our guide and mentor, through a conducted tour of the works. He shows us diagrams of the by-products of coking which are absolutely unsuitable for film use. They are black and white organigrams of the family tree type. The writing is so small that when you can see the whole chart it is impossible to read the writing. It would certainly have been worth while to use colour and design to make these charts truly meaningful in a film which is avowedly educational in intent.

This is symptomatic of the whole treatment. The visuals never show what is happening. We only see the outsides of the various installations and pieces of equipment. We never see inside. The chemist gives us a lecture in which the words are all too seldom linked with the visuals.

As the film tours the works the face of the chemist, which is long and somewhat saturnine, but invariably smiling, is always in the foreground. This personalised approach is pleasing for the first five minutes, after which it becomes progressively more irritating. When his voice is drowned by the sound of machinery, and we can't hear the commentary, the first impact is a gentle chuckle. After this device has been repeated a number of times, one feels frustrated. Surely he knows the works and can take the trouble to let us hear what he is saying.

The film continues, we know every well brushed black curl and every wrinkle on the chemist's face, but we know little more about the coking process. In fact, your reviewer had given up the unequal task of trying to follow the logic and instructional method of the film.

So much trouble, thought and expense, has been devoted to making this film, that it is regretted that it cannot be praised. It is a pity that when there is an interesting subject which needs film exposition, that film makers forget their subject is searching for a gimmick-studied vehicle. Yes, it is interesting to go round with a personalised character, but when he opens his umbrella because water is spraying round, the first reaction is "so what?" The second reaction is: "Where did the water come from? Is it part of the process or merely rain?" To this moment your reviewer does not know, and this is the measure of the film's failure.

Back in the office the audience is shown various products made from by-products of coke, but the way in which they are shown is perfunctory. The outside of a pot of paint and a jar which is never opened. The scene is stolen by the slow entry of a model posing as a typist who brings in tea, and we are given plenty of time to appreciate her charms. A science master sitting next to me said "That'll go down well with the fifth form."

This criticism is not intended to be scathing. It is meant to be constructive. The idea was good on paper, unfortunately it fails on celluloid. The same type of thinking, if more severely disciplined, more logical and more scientific, can, in the future produce very valuable educational films on a subject which is insufficiently covered at present. L. GOULD-MARKS

Stone into Steel

16 and 35 mm. Eastmancolor. Sound. Running time 37 minutes. Produced for the United Steel Co. Ltd, by Wallace Productions Ltd, written and directed by Paul Dickson in collaboration with Sam Lock, Photography by Wolfgang Suschitzy.

As this film is unique among modern sponsored Public Relations films, it needs careful analysis and consideration. Therefore it seems wise to summarise the content before discussing the treatment.

The film was made at the Appleby-Frodingham Steel Works at Scunthorpe, Lincolnshire. It is the largest single unit of the United Steel Group of Companies and employs 11,000 men. It produces 1,400,000 tons of steel a year. Five million tons of ironstone are extracted from the Lincolnshire and Northamptonshire Orefields each year.

The processes by which this stone is turned into steel is the theme of the film. It begins with a few simple sub-titles rolling down the screen against a background of abstract-seeming photographs of ore and stone. From this moment onwards the audience is left to learn and understand the processes by eye alone.

Thirty-seven minutes is a long time for an experimental film to run. In this case a bold and interesting experiment is carried on long after its point has been proved. Beautiful photography picks out the visual high points of the plant and the process. Brilliant visual editing stimulates the eye and the brain. The musical score, composed specially by Edward Williams, and played by the Sinfonia Orchestra of London, conducted by Marcus Dods, tries gallantly to hold the mood. Sometimes it succeeds and sometimes it limps slightly.

As this is an adult film, it must be prepared to withstand criticism.

Paul Dickson, the Director, after his notable success in the paraplegic film, *The Undefeated* reached a very high level. He is obviously trying here to experiment with the exciting visual cutting of the early Russian Film Directors like Pudovkin. The Russians worked in black and white, using light and shade to give emphasis. Dickson works with colour. Individual shots are exciting. Juxtaposition and montage stimulate—but it is almost impossible to remain stimulated for thirty-seven minutes.

If this film had been cut with the ruthless courage with which it is made, it would be a classic, worthy of a permanent place in the scientific and film societies' catalogues. As it is, every sequence is carried on almost *ad nauseam*. It is not a question of cutting out the last two reels. It is a matter of reducing every single sequence in the film. If it moved with speed as well as beauty it would hold its audience. As it was my next-door neighbour slept peacefully after the first twelve minutes. If only this film could be reduced to fifteen minutes maximum, most of your reviewer's criticisms would be overcome.

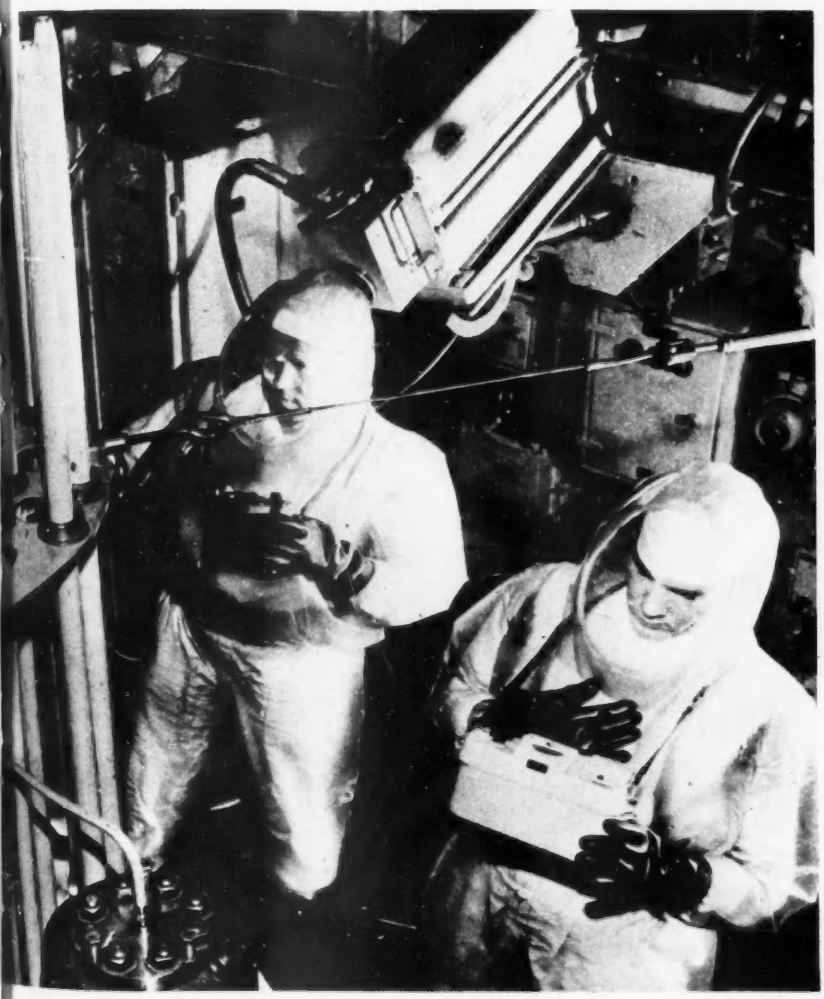
From the scientific point of view, and from the instructional and educational standpoint, the silent film is a retrogressive step. This is a silent film with the same sort of accompaniment in practise as used to be thumped out from the orchestra pit. When there are complex processes to be described it is not really enough to see conveyors, molten metal, laboratory tests and control gear. Mass media, like film, should communicate. The few sub-titles as the very beginning will soon be forgotten.

As an exercise in film making this is very valuable. It is very difficult to see, however, exactly at which audience it is aimed. L. GOULD-MARKS

FAR AND NEAR

RUSSIA'S NEW ATOMIC ICE-BREAKER MAKES MAIDEN VOYAGE

The new Russian atomic ice-breaker *Lenin* made her maiden voyage in the Arctic recently. The trip lasted for twenty days during which the Soviet seamen and experts carried out ice study, needed for the forthcoming arctic navigation.
LEFT: View of *Lenin* during her maiden voyage.
LEFT (*below*): Dressed in protective clothing, two technicians checking for radiation aboard the *Lenin*.
(A full description of the *Lenin* was published in DISCOVERY, Vol. 19, 1958, No. 12, p. 498).



Symposium on Rocket and Satellite Instrumentation

The Society of Instrument Technology and the British Interplanetary Society are to hold a one-day Symposium in London on September 1, 1960, during which approximately eight papers will be presented on "Rocket and Satellite Instrumentation".

The papers proposed are as follows:

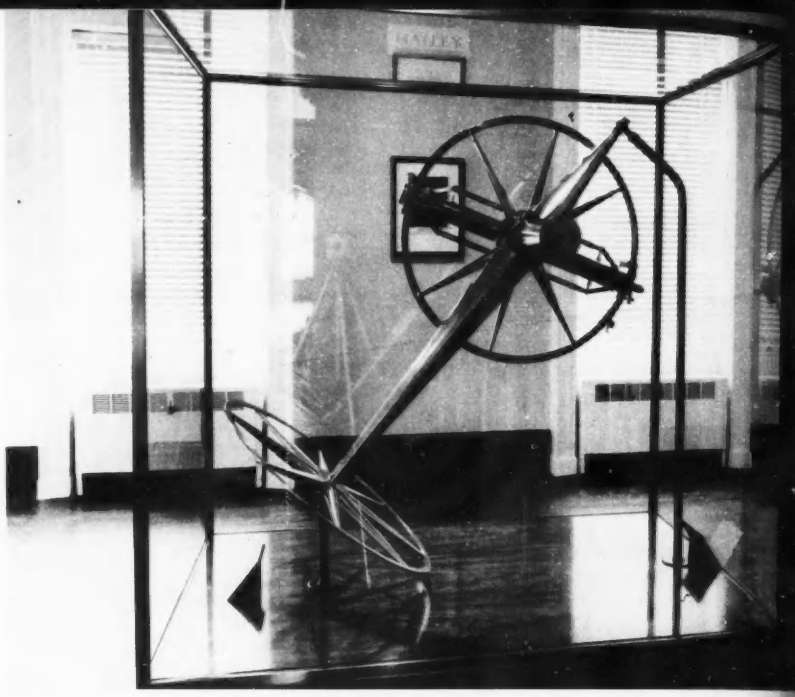
1. Outline of the Investigations Planned for the British Space Programme.
2. A Design Study on a Communication Satellite.
3. A Digital Data Reduction System for Use in the Static Testing of Rocket Motors.
4. Transducers for Rocket Motor Testing.
5. The Measurement, Transmission and Recording of Data in the *Skylark*.
6. Ultra-violet Measurements from Satellites.

7–8. Subjects to be decided.

The object of the Symposium is to indicate the fields of new scientific knowledge which have been opened up by experiments in the upper regions of the atmosphere and in outer space and to describe the kind of instrumentation which has either already been used or will be required for future research.

New Gypsum-based Industry in Israel

A research project aimed at developing an important new industry based on local gypsum was recently launched under pilot plant conditions by the Building Research Station of the Technion, Haifa, Israel. As used in contruction abroad, gypsum is commonly called plaster of Paris.

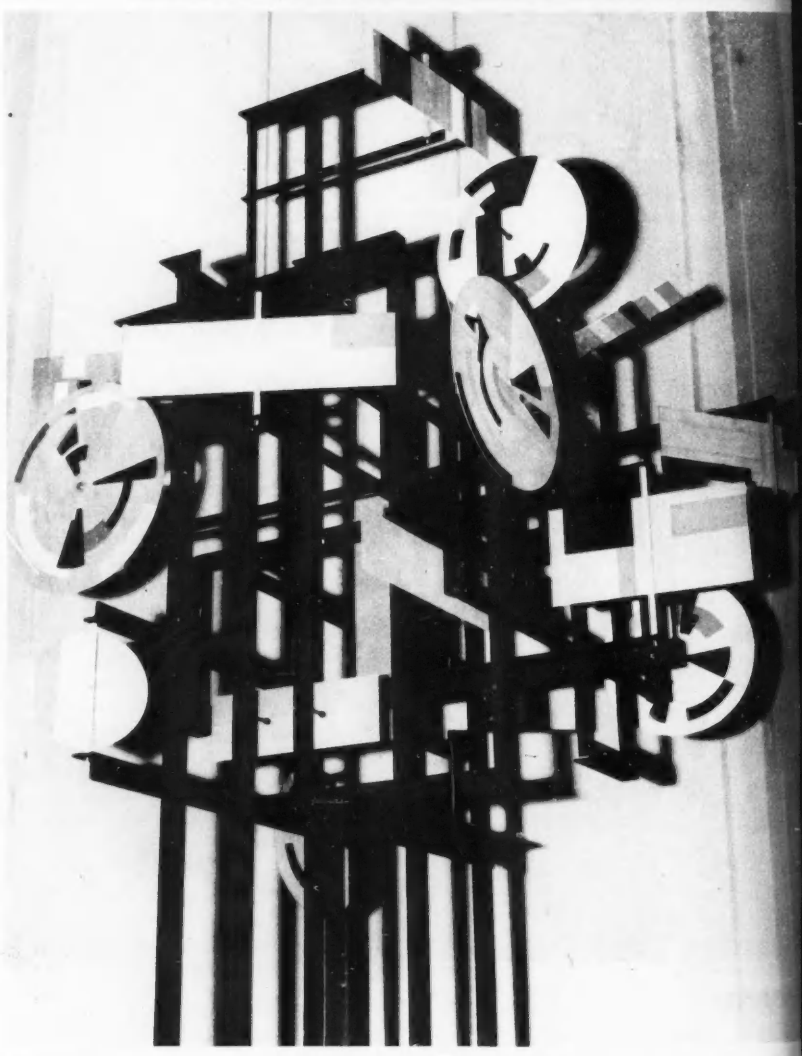


FLAMSTEAD HOUSE TO FORM PART OF NATIONAL MARITIME MUSEUM

(*Right*). The Building is a section of the Royal Observatory Buildings at Greenwich—and is a striking eight-sided tower on top of the hill in Greenwich Park. It was designed by Sir Christopher Wren in 1675. An equatorial telescope in the Halley room—made and designed by Jonathan Sisson. (This beautiful photograph is unfortunately spoilt by the photographer's lights and his camera.)

EXHIBITION OF UNUSUAL SCULPTURE

(*Below right*). An Exhibition of Spatio-dynamic, Cybernetic and Luminodynamic sculpture, by Nicolas Schoffer recently held in London at the Institute of Contemporary Arts. The object of the picture is Spatiodynamique 7.



The programme, established through a grant of the Ministry of Commerce and Industry, will be set up to manufacture special types of plaster board for construction purposes, developed after extensive research in the Building Research Station located at Technion City.

When brought into full use in local construction, the new types of board may free for export other locally made building materials such as plywood, asbestos, cement sheets, masonite, and celotex.

The latest programme for the development of gypsum, a material found in almost limitless quantities in various parts of Israel, comes as a result of years of research into the potentialities of this material. Investigations at the Technion laboratories had already established the feasibility of using local gypsum, and has set up an impressive list of its possible uses.

History of Science Congress

The Xth International Congress of the History of Science will be held in the United States of America, August 26–September 2, 1962. Opening sessions of the Congress will be held at Cornell University, Ithaca, New York, and the concluding sessions will be held at the American Philosophical Society, Philadelphia, Pennsylvania. The President of the Congress is Prof. Henry Guerlac of Cornell University. The Secretary of the Congress is Prof. C. Doris Hellman.

All inquiries should be addressed to The Secretary, Xth International Congress of the History of Science, Cornell University, Ithaca, New York (USA.). Those wishing to receive bulletins concerning the congress are requested to communicate with the Secretary.

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